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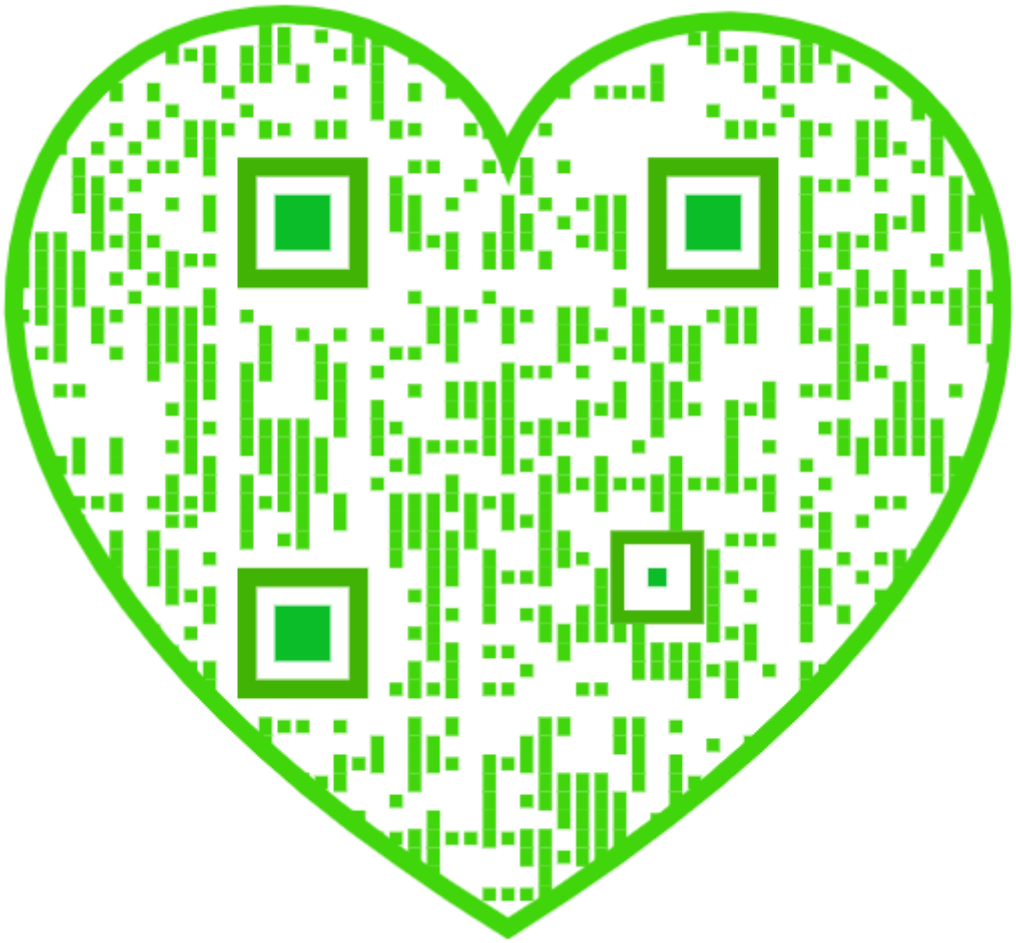

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THE

ELEMENTS OF CHEMISTRY

AS APPLIED

TO AGRICULTURE.

By C. B. CHAPMAN, A. M., M. D.,
PROFESSOR OF CHEMISTRY.

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PREFACE.

THE importance of placing before the youth in our schools, as well as in the hands of our farmers at their homes, the means of acquiring a knowledge of the elements of the science and art of agriculture, has long been acknowledged by teachers and others.

Such means have already been available to those who had acquired a limited knowledge of chemistry; but the most valuable works, containing the facts most useful to the practical farmer, have been too voluminous and expensive for his own use and means, or too technical for the use of his sons while in the common schools.

The material which is offered in this treatise, is the result of considerable practical observation, and has been used by the author, in his lectures to classes, during several years of professional labor.

The improvement which was apparent in these classes, has encouraged him to believe that the same materials might be used with advantage and profit by teachers and pupils in public schools, especially in those districts where the people are generally engaged in agricultural pursuits.

The day has gone by when farmers were esteemed the most ignorant among citizens, and it is now held absolutely necessary for success, as well as indispensable to proper social standing, that farmers should be educated thoroughly in their calling.

If the author shall have contributed anything to aid the farmer in his important work, or to furnish for young men who are looking forward to this vocation, the means of more thorough preparation for their honorable and useful calling, his object in giving to the public this unpretending volume will be attained.

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INTRODUCTION.

In order to understand the first principles of agriculture, as a science, it is necessary that some of the simple lessons in chemistry should be learned; and these are best taught in the same manner as the elements of that science are presented in the common text-books.

There is no royal road to knowledge in any department of science, although the avenues to these acquirements may be greatly improved by the adoption of a well-adapted arrangement of lessons; and to make the best use of these lessons, it is necessary that a small amount of apparatus should be used; but the arrangement of illustrations is such, that this is not indispensable to their profitable use in the school-room.

Teachers may too often be deterred from the attempt to use apparatus, for illustrating their lessons, on account of not having tested their ability to do so. Such may be assured, that, with proper care in observing the directions given, for the purpose of aiding teachers in their first attempts, they will be surprised to discover the facility with which they will succeed.

There are some principles, or facts, in agriculture, which apply peculiarly to each country or locality; but these are

found mostly to apply to the mechanical condition of soils; and such as are remedied by DRAINAGE, PULVERIZATION, and MIXTURE with substances which will render the arrangement of its particles such as to subserve the uses of the plant we propose to raise.

There are other principles which apply alike to all countries and localities; for each plant, as well as each animal, requires certain elements as food, or material out of which their tissues are constructed.

The first scientific facts, or principles, in agriculture, are few and extremely simple; but it is no less important that they should be thoroughly acquired, than that one who proposes to learn a language, should, first of all, become familiar with its alphabet.

Many persons, already engaged in agricultural pursuits, have, most likely, been deterred from the effort to acquire these first principles, by the belief that more time would be required for its accomplishment, than would be compatible with their other avocations.

It has been the aim of the author so to condense the statement of the facts which are involved in the chemistry of this art, that the work might be adapted, not only for use in the school-room, but for fireside perusal, and thus furnish the means for rendering our young farmers as well versed in the science which belongs to their chosen pursuit, as those of any other country.

The farmer has too often been led to believe that *his* experience is worth more to him than those aids which he can derive from science; but such persons should be aware, that to become familiar with the principles of the science upon which his art is based, can most surely do him no

harm, and will, at least, enable him to judge more correctly, with regard to the value of *his experience*, when thus compared.

The wealth of the merchant is increased, only by the well-directed employment of his capital. On the same principle, the wealth of the farmer is mostly augmented by the best use of his grounds; and this consists in adapting his crop to the present condition of his field, so that when defective, he supplies such manures as are best calculated to improve the crop he proposes to raise.

In some instances, instead of furnishing manure to his field, he may introduce such crop as can be sustained by materials which the soil already contains.

SOIL and MANURE, in a certain sense, are the farmer's capital; and while manures are cheap, and often furnished without the outlay of capital, especially when their nature is understood, the crops which they contribute to improve are sold for a considerable sum. That which was cheap, and in some instances worthless, is, by the processes of the farmer, converted into that which is valuable.

This is the only rational basis on which the farmer is enabled to estimate the value of his capital, and his only sure guide in selecting the best methods for its employment. A superabundance of food is no more useful for a plant than for an animal; and consequently nothing is gained by adding a substance as a manure which already exists in sufficient proportion in a soil.

There is no common material in soils, the use of which the farmer is more interested in properly understanding, than lime. This substance, when artificially used in its

various combinations, may be employed to correct any excess, either of alkalies, or of acids; in accordance with the nature of the elements which enter into the formation of the article employed.

The tests for determining the presence, and excess, of either alkalies or acids in soils, are so simple, and so easily applied, that they may be used by the farmer without seeking an analysis by the practical chemist, although a careful analysis, which will reveal the exact materials of which his soil is composed, will often be a most useful investment for him, although attended with some expense.

For determining the presence of acids, or alkalies, he has only to employ two common substances, which will be found in the shops. These are an acid (sulphuric, or chlorohydric) for determining the presence of an alkali, or an alkali (ammonia), to test the presence of an acid.

By ascertaining whether a soil contains an acid or an alkali, in excess, the farmer may save the unnecessary expenditure of much time and labor, as well, perhaps, as of a costly manure; for it has too often been true, that as to their constituents, manures have been applied indiscriminately, whenever a soil has been found unequal to the production of a crop. This is but a simple example of the value of chemical knowledge to the farmer, and shows how easily and cheaply tests which may reveal facts of great practical utility, may be employed by every farmer.

AGRICULTURAL CHEMISTRY.

CHAPTER I.

TABLE AND SYNOPSIS OF ELEMENTS.

THE language used in works on chemistry possesses peculiar advantages, in its brevity by the use of symbols, thus presenting to the eye, in a simple familiar operation and results, the description of which would otherwise confuse the mind by its length and complexity.

The whole number of elementary substances is but fifty-nine.

An elementary body is one which can not by any known process, be divided, and thus made to assume different forms. WATER, although it appears to us as a simple body, may be analyzed by processes which are easily practiced by the chemist, and thus resolved into the two elements of which it is composed.

These elements are oxygen and hydrogen gases, neither of which can be again subdivided, but can be made to unite with still other elements, and thus produce other

---

What means are used to express the language of chemistry? What is the number of elementary substances?

What is an elementary body? Of how many elements is water composed? What are they? Can either of these be again divided? Will they unite with other elements?

compounds, which will be found to possess none of the properties of the original elements of which the body is composed.

It has been discovered, that when elements unite among themselves, it is invariably in certain fixed proportions, or weights, or their multiples.

Water is composed of oxygen and hydrogen, which are here united in quite different degrees of weight and bulk, for the weight is in the proportion of one of hydrogen to eight of oxygen, while the hydrogen, when free, will occupy twice the space of the oxygen; or a given bulk of oxygen will weigh sixteen times as much as the same bulk of hydrogen.

As hydrogen is found to unite with other bodies in a smaller weight than any other known element, it has been commonly adopted as the basis of unity of the scale of equivalent numbers.

In the following table, hydrogen is represented by the figure *one*, and the combining or atomic weight of each of the other elements, are rated in proportion from this number.

The symbols are expressed by the first, or the first and one other letter of the name of the elements, and the atomic weight is represented in the right hand column.

Will compounds produced by such union possess any of the properties of their original elements? In what way do elements unite?

In what proportions, by weight, are the elements of water united? In what proportions by bulk?

What element is adopted as the basis of unity of the scale of equivalent numbers? What figure represents hydrogen?

How are symbols expressed? Where is the atomic weight represented?

[*Table of the whole number of known elements.*]*

Aluminum	Al.	13.69	Nickel	Ni.	29.57
Antimony (stibium)	Sb.	129.03	Niobium	.....	.....
Arsenic	As.	75	Nitrogen, or Azote	N. or Az.	14
Barium	Ba.	68.64			
Bismuth	Bi.	70.95	Osmium	Os.	99.56
Boron	B.	10.90	Oxygen	O.	8
Bromine	Br.	78.26	Palladium	Pd.	53.27
Cadmium	Cd.	55.74	Pelopium	.. ...	.....
Calcium	Ca.	20	Phosphorus	P.	32.02
Carbon	C.	6	Platinum	Pt.	98.68
Cerium	Ce.	46	Potassium (kalium)	K.	39.00
Chlorine	Cl.	35.50	Rhodium	R.	52.11
Chromium	Cr.	28.15	Ruthenium	Ru.	52.11
Cobalt	Co.	29.52	Selenium	Se.	39.57
Copper (cuprum)	Cu.	31.66	Silicium	Si.	21.35
Didymium	D.	49.6	Silver (argentum)	Ag.	108
Fluorine	F.	18.70	Sodium (natronium)	Na.	22.97
Glucinum	Gl.	26.50	Strontium	Sr.	43.84
Gold (aurum)	Au.	98.33	Sulphur	S.	16
Hydrogen	H.	1	Tentalium or Columbium	Ta.	92.30
Iodine	I.	126.36	Telurium	Te.	66.14
Iridium	Ir.	98.68	Thorium	Th.	59.59
Iron (ferrum)	Fe.	28	Tin (stannum)	Sn.	58.82
Lanthanum	Ln.	48	Titanium	Ti.	24.29
Lead (plumbum)	Pb.	103.56	Tungsten (wolfram)	W.	94.64
Lithium	Li.	6.43	Uranium	U.	60
Magnesium	Mg.	12.67	Vanadium	V.	68.55
Manganese	Mn.	27.67	Yttrium	Y.	32.20
Mercury (hydrargyrum)	Hg.	100.07	Zinc	Zn.	32.52
Molybdenum	Mo.	47.88	Zirconium	Zr.	33.62

Three others have been referred to in some works, but these are of still less importance than any of those contained in the table.

These are Erbium, Norium, and Terbium.

Only fourteen elements are common, either in the composition of the EARTH, WATER, or ATMOSPHERE. Enumerated with these are two others, but they exist in very small quantities, as constituents of soils.

How many elements are common in the earth, water, and atmosphere? What others exist in small quantity in soils?

* Graham's Elements of Chemistry.

When set free, and at common temperatures, much the largest number of the elements are solids. Five are gases, namely: OXYGEN, NITROGEN, HYDROGEN, CHLORINE, and FLUORINE. MERCURY and BROMINE, only, are fluids.

Some of the elementary bodies exist free in nature, and were known long before the science of chemistry had imparted a knowledge of their true character and relations. Among these were several of the metals, as IRON, COPPER, GOLD, SILVER, MERCURY, LEAD, and TIN.

Others, as POTASSIUM, SODIUM, CALCIUM, MAGNESIUM, as well as the largest number of common substances, are found in nature only in combination with other elements, the principal of which is oxygen.

CHAPTER II.

UNION OF ELEMENTS FORMING COMPOUNDS; NOMENCLATURE AND SYMBOLS.

THE union of two or more elements produces a compound, and such compound commonly derives its name from the original substances of which it is composed. The materials which enter into the formation of a compound

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In what condition are the largest number of elements found? How many are gases? How many are fluids?

Do some exist free in nature? Which have long been known? Combined with what are the largest number found?

What does the union of two or more elements produce? Whence does such compound derive its name?

may be most easily expressed by a language of symbols. Such would by no means be true, if the number of original elements were equal to that of the compounds which they contribute to form.

The whole number of elements is but fifty-nine, and, consequently, the symbols which are used to express these elements can only correspond to that number. When more than one atom of a given element enters into a compound, such additional atoms are commonly expressed by a small figure at the right of the symbolic letter. Thus, CO_2.

The number of elements which will be described in this work is but sixteen, and two of these need be but briefly considered as elements connected with the organization of living beings. No more than sixteen symbols, then, will be used in expressing these elements.

Example.—CARBONIC ACID being composed of two elements, *carbon* and *oxygen*, and the proportion of these being one of carbon, and two of oxygen, this compound gas is thus expressed in symbols, CO_2.

As the equivalent number for carbon is 6, and that for oxygen is 8, it would be one of carbon, 6, and two of oxygen, twice 8—or the whole would be expressed in figures, when added together, by 22.

How may such materials be most easily expressed? Would this be true if the number of elements was equal to that of the compounds which they form?

To what does the number of symbols correspond? When more than one atom of an element, how expressed?

What number of elements are described in this work? Then, how many symbols are used in it?

Of what elements is carbonic acid composed? How many atoms of carbon? How many of oxygen?

How is carbonic acid expressed in symbols?

No figure is used when there is but one atom of an element; for the symbolic letter is understood to stand, not only for the element, but for one atom of the element.

Elements unite with each other in fixed and invariable proportions, and the figure on the right of the symbol in the table of elements, always represents these proportions.

If more than one equivalent of any given element unites with another, it is never united in parts, but in another whole equivalent proportion.

Example.—WATER is composed of one equivalent, or atom, each, of oxygen and hydrogen, and is expressed in symbols thus, H O.

Nine pounds of water are composed of one pound of hydrogen and eight pounds of oxygen.

BINOXIDE OF HYDROGEN is formed of one equivalent of hydrogen, and two of oxygen, and is expressed in symbols thus, $H O_2$.

Seventeen pounds of binoxide of hydrogen are, consequently, found to be composed of one pound of hydrogen, and sixteen pounds of oxygen.

A combination of two elements will produce a third substance, entirely unlike either of the original elements of which it is composed, and when the proportion of elements is different, the product will also vary, both in properties and appearance.

Is a figure used when there is but one atom of an element?

Do elements unite with each other in invariable proportions? How is water expressed in symbols?

How binoxide of hydrogen? Of how many pounds of each are seventeen pounds of binoxide of hydrogen composed?

Does the union of two elements in different proportions always produce a different substance?

The union of two elements in different proportions will produce entirely different substances. The union of one atom of oxygen and one of hydrogen, will produce water, and nothing else. The union of one equivalent of hydrogen and two of oxygen, will form binoxide of hydrogen, a substance which will not possess any of the properties of water.

A good illustration of the change in the character of substances, as influenced by variation in the number of equivalents of elements which compose them, may be observed in those entirely different compounds which are formed of oxygen and nitrogen, the two elements which compose the atmosphere. These two elements are not chemically combined in the formation of the atmosphere, but their particles float in relation with each other by that method which is properly called mixture.

The chemical combinations of these elements are five in number, and are expressed by the following symbols:

Protoxide of Nitrogen, ...N O.
Deutoxide of Nitrogen, ...N O_2.
Hyponitrous Acid, ...N O_3.
Nitrous Acid, ...N O_4.
Nitric Acid, ...N O_5.

The first two of these are properly called oxides, and exist in the form of gases.

Does the union of like atoms always produce a like substance? Give two examples. Of what two elements is the atmosphere composed?

Are these chemically combined? What is the number of chemical combinations of nitrogen and oxygen? What are the two first called?

The first (protoxide of nitrogen, NO) can be inhaled by the lungs, when it produces a peculiar exhilarating effect, which has given it the common name of laughing gas.

The second, (deutoxide of nitrogen NO_2,) although a gas, can not be received into the air passages; for it excites a violent spasm in the larynx, when an attempt is made to inhale it.

The last three are acids, and exist in the liquid form; but their properties, and the purposes which they serve, are quite different.

Hyponitrous acid, NO_3, is a thin liquid. At common temperatures its color is green; but, when cooled down to zero, it becomes quite colorless.

Nitrous acid, NO_4, when at a low temperature, is a colorless liquid; but it becomes yellow as the temperature rises.

Nitric acid, NO_5, is the only one of these five compounds which is of any special importance in the arts.

This powerful acid was first known some time in the ninth century, and with its discovery may be regarded the beginning of a knowledge of chemistry. It was long known as *aqua fortis*, which name it bore on account of the great power which it possesses of acting upon, and uniting with, most of the hard metals.

Its corrosive action upon all animal and vegetable (organic) substances, is immediate, and very powerful.

What are the properties and effects of the first? What of the second? What are the last three properly called?

What symbols express each of these? Which of these is of especial importance in the arts?

What was its early name? Why this name?

COHESION AND AFFINITY.

The attraction of *cohesion* is understood to be that force which retains particles of a like kind, "with various degrees of tenacity," in relation with each other, as the particles of a mass of metal, of which gold, silver, iron, and lead, may be taken as examples.

The attraction of *affinity*, in chemistry, is that union of substances which takes place between two elements, or bodies, which are unlike in their properties, in order that they may unite, and form a compound.

This change takes place between such substances only as are quite diverse in their character, as an acid and an alkali.

When an acid unites with an alkali a union takes place between them, and a third substance is produced. Such compound is entirely different from either of the original substances, both in appearance and in general properties. The product of such union is called a SALT.

The tendency to union between any given alkali, and the different acids, is quite unlike.

Example.—If the alkali selected be soda, the tendency to union, or to remain united, which indicates the strength of affinity, is indicated by the following table, soda being the alkali used in the experiment:

SODA, as the alkali, or base,
Sulphuric acid,
Nitric acid,

What is the attraction of cohesion? What that of affinity? What does the union of an acid and an alkali produce? Is the tendency to union between any alkali and the different acids alike?

Chlorohydric acid,
Acetic acid,
Carbonic acid.

Those which most strongly resist separation from the base are found at the top of the table, and others are placed in succession, in accordance with their strength of affinity for the alkali. Thus: sulphuric acid may be used to secure a resolution of the union which exists between the soda, and any of the acids which are placed below them in the table.

CHAPTER III.

AGRICULTURE DEFINED.

THE oldest, the most universal, as well as the most indispensable of human employments, is agriculture.

Upon the practice of this art not less than eight hundred millions of human beings depend for their daily sustenance, and about eight-tenths of the inhabitants of the globe expend in it their daily labor. Something like two hundred millions of the inhabitants of the world subsist on such products of the earth as do not require the skill of husbandry.

In the earliest periods of the world's history the prac-

Name the order of affinity between soda and the five acids mentioned.

Where, in the table, is the acid which has the strongest affinity for soda placed?

Which is the oldest of employments?

tice of agriculture was confined to the raising of a few kinds of grain, and the care of herds of cattle.

To the art of agriculture belongs a knowledge of the best methods of putting the seed for the various crops into the ground, of attending to them during the period of growth, of harvesting them at the proper time, and storing them away for future use, or preparing them for market, and each of these with the smallest expenditure of time and labor.

The methods by which these operations are performed embrace what is called MECHANICAL AGRICULTURE.

Another department, which must be understood in order to the most economical pursuit of agriculture, involves a knowledge of the elements of which the plant is composed, of the soil from which it grows, and of the various manures which are used to enrich the soil, or to furnish food for plants.

This is called SCIENTIFIC AGRICULTURE.

Agriculture is pursued, then, both as a SCIENCE and as an ART.

In no country have mechanical devices which are intended to save the time and labor of the farmer, been more extensively introduced than in the UNITED STATES.

The applications of science to agriculture have, however, been more carefully studied, and are understood by a larger proportion of agriculturists in the countries of EUROPE, especially in GREAT BRITAIN, FRANCE, GERMANY and BELGIUM, than in the UNITED STATES.

What belongs to this art? In how many divisions is agriculture studied? What are they? What is mechanical agriculture?

Where is mechanical agriculture best understood? Where scientific?

This knowledge is more necessary for the inhabitants of those countries, on account of the numerous population, for which a limited amount of land must furnish subsistence.

For this reason, in China the skillful cultivation of the soil is still more demanded than in any other country.

An acquaintance with both mechanical and scientific agriculture is necessary to enable the farmer to raise the largest crop with the least possible injury to the soil, the smallest expenditure of time and labor, and the most economical investment of capital.

CHAPTER IV.

MATERIALS OF WHICH THE EARTH IS COMPOSED.

ALTHOUGH the number of elements which compose the EARTH, AIR, and WATER, as well as the ANIMALS which exist on the globe, and the PLANTS which grow from its surface, are but fifty-nine: only sixteen of these are known to form any considerable portion of the whole mass of which they are severally composed.

ORGANIC ELEMENTS.

Four of this number enter principally into the formation of plants and animals, and are therefore distinguished

---

Why is this knowledge more necessary in European countries? Where still more demanded? Why is a knowledge of both mechanical and scientific agriculture required?

How many elements form any considerable portion of the crust of the earth—of air, water, and plants?

as ORGANIC ELEMENTS. These are CARBON, NITROGEN, OXYGEN, and HYDROGEN.

The other twelve exist in much smaller proportions in organized substances, but enter largely, though in very different proportions, into the formation of the crust of the earth.

These are POTASSIUM, SODIUM, MAGNESIUM, CALCIUM, SULPHUR, CHLORINE, FLUORINE, PHOSPHORUS, SILICIUM or SILICON, ALUMINUM, MANGANESE, and IRON.

Ten substances, which are mostly compounds with oxygen, form the principal inorganic constituents of soils.

These are POTASH, SODA, LIME, MAGNESIA, SILICA, CHLORINE, PHOSPHORIC ACID, SULPHURIC ACID, OXIDE OF IRON, and OXIDE OF MANGANESE.

The first four of this group are called ALKALIES, and may be distinguished by a peculiar taste, called *alkaline*, as well as by their power to restore vegetable blues, whenever they have been changed to red, by the action of an acid upon them.

POTASH

Is the strongest of the alkaline substances.

It acts so powerfully upon the flesh of animals, and upon green vegetables, as to decompose them in a few hours. In the form in which it is commonly found in

---

How many organic elements proper? What are they? What are the other twelve?

How many substances form the principal inorganic constituents of soils? With what are they mostly compounds?

What are they? How many and which are alkalies? What distinguishes an alkali?

How is potash distinguished? How does it affect animal and vegetable matter?

the shops, it is a white substance; and, unlike others of the same class, when exposed to the air, it absorbs much moisture, by which it becomes soft, and finally nearly liquid.

POTASH is obtained by dissolving the soluble portion of wood ashes, and evaporating the solution by boiling, when it remains in the vessel as a hard mass.

In this form it is used in the manufacture of SOAP, which is formed by its combination with OIL. It is also used in the manufacture of GLASS, in which process it must be intensely heated with SILEX.

POTASH exists naturally in some soils, especially in those latitudes where the successive growth and decomposition of such plants as contain large quantities of it succeed each other with great rapidity.

When potash is exposed to an atmosphere which contains carbonic acid, it absorbs a portion of that gas, and is converted into *carbonate of Potash*, or PEARLASH. This is expressed in symbols $K\,O,\ C\,O_2$.

When another atom of carbonic acid is absorbed, it produces a *bicarbonate of Potash*, or SALERATUS; which is expressed by $K\,O,\ 2\,C\,O_2$.

POTASH unites with SILICA, and forms SILICATE OF POTASH. This compound is readily dissolved in water, by which it is enabled to circulate through the vessels of

---

What is its appearance? How affected by moisture? How is potash obtained?

For what purpose used in the arts? What combined with to form soap? To form glass?

Where does potash exist naturally? What takes place when potash is exposed to an atmosphere which contains carbonic acid?

What when another atom of carbonic acid is absorbed? What does potash and silica form?

plants. This is the principal source from which silex is furnished to growing plants.

SODA

Is a white, crystalline substance, which, unlike potash, remains dry when exposed to the atmosphere. It was formerly manufactured from the ash of sea-weeds, or *kelp*, but is now mostly produced from sea water, where it exists in combination with chlorine, which union forms CHLORIDE OF SODIUM, or common culinary salt.

The principal difference in the soda produced from these two sources, is, that IODINE exists in the ash of plants which grow in sea water.

SODA, like POTASH, is used in the manufacture of SOAP and GLASS.

The most common forms in which soda is found in the shops is a carbonate and bicarbonate. Another common form is the sulphate, which is commonly known as glauber salts.

LIME

Exists in nature in great abundance in combination with carbonic acid, or as a CARBONATE. The forms of carbonate of lime are three in number; and, although composed of the same elements, their appearance is quite different, and their uses are equally diverse.

These forms are as LIME ROCK, MARBLE, and CHALK.

For what is this used by plants? Describe soda. From what was it formerly manufactured? From what now manufactured? What is common salt? What in addition does kelp contain?

For what is soda used in the manufactures and arts? In what form is it most commonly found in shops?

In what form is lime mostly found? What are the forms of carbonate of lime?

Nine-twentieths of the weight of lime rock is diminished by the application of heat, as in the common lime-kiln.

By this process the carbonic acid which it contains is driven off into the atmosphere, where it constantly exists, in the proportion of four parts to ten thousand. The portion that remains in the kiln is quick-lime.

When water is poured upon quick-lime, or when it is exposed to the atmosphere from which it absorbs water, heat is evolved; and this corresponds with the amount of water which is absorbed in a given time. As soon as heat becomes apparent, the lime crumbles to a powder, increases rapidly in weight, and assumes a form which is called the HYDRATE OF LIME.

When further exposed to the atmosphere, carbonic acid is absorbed, and the mass gradually returns to the condition of a carbonate of lime.

Lime also exists in nature as a sulphate; and in this form is commonly known as gypsum, or plaster. When the water which it contains has been expelled by heat, it forms a material which is used for STUCCO and PLASTER CASTS, and when thus prepared is known as PLASTER OF PARIS.

The fine, white, and variegated varieties, are called ALABASTER.

How much is lime rock diminished in weight in the lime-kiln? What is driven off? What is left?

What proportion of carbonic acid exists in the atmosphere? What takes place when water is poured upon lime? What effect upon its condition and weight? What is it then called?

What takes place when further exposed to the atmosphere? In what other form does lime exist in nature? What are the fine, white, and variegated varieties called?

MAGNESIA

Is abundant in nature in many rocks, in union with lime, where it takes the name of MAGNESIAN LIME ROCK.

Magnesia is found in the shops in three forms: in a very light white powder, as a CALCINED MAGNESIA; in irregular lumps, but also very light, as a CARBONATE; and in union with sulphuric acid, forming a salt, which is called a sulphate, or EPSOM SALTS.

SILEX,

Or SILICA, is formed by the union of oxygen with Silicium or Silicon, and is commonly known as ROCK CRYSTAL, QUARTZ, FLINT, SAND, and SANDSTONE.

It exists in the stems of some plants, to which it seems to furnish the principal support.

It is found most abundant in the straw of wheat, rye, oats, and barley, and in the stalk of Indian corn. For these purposes it is derived directly from the soil.

In the arts it is used in the manufacture of GLASS, PORCELAIN, and the various kinds of STONE and EARTHENWARES.

CHLORINE

Is a heavy gas, of a greenish yellow color, and has a strong, suffocating odor.

A taper will continue to burn freely in it, but with a dim, smoky flame.

Where does magnesia exist in nature? In what forms is it found in shops?

What is epsom salts? How is silex formed? By what different names commonly known?

In what part of plants found? For what purpose used in manufactures? Describe chlorine. What effect on a burning taper?

It is extremely irritating to the respiratory passages, when breathed even in the smallest quantities. It forms a large proportion of common salt, (Chloride of Sodium,) and an equal proportion of sal ammoniac, (Chloride of Ammonia.) The proportion of chlorine in each of these salts is sixty to every hundred pounds.

Chlorine gas is easily prepared by adding chlorohydric acid to the oxide of manganese in a retort, or gas bottle, and applying a gentle heat.

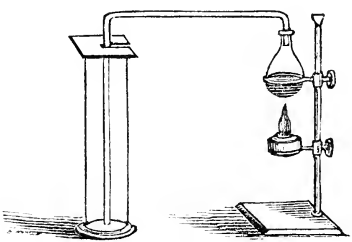

Fig. 1.

It may be collected in small quantities for immediate use, in a tall jar, by displacement; for its specific gravity is nearly two and a half times greater than that of the atmosphere. When gathered over a pneumatic trough, like other gases, hot water, or a strong solution of common salt must be used, else much of the gas will be absorbed. Pure cold water will retain twice its bulk of chlorine, and this is a convenient method for retaining the gas for some purposes.

This gas, as well as those compounds which produce it abundantly and economically, is used in the art of bleaching.

What effect on air passages? It forms a large proportion of what?

How is chlorine prepared? In what way is it collected? Why can it be gathered by displacement?

Why necessary to use warm water or brine? In what art is it used?

PHOSPHORIC ACID

Is a solid white substance, which is seen, like white smoke, floating in the atmosphere after the burning of a common friction match. It is there formed by the oxygen of the atmosphere uniting with the phosphorus, which is combined with sulphur in the manufacture of matches. It exists in the bones of animals in very large proportion, in combination with lime, where it takes the name of phosphate of lime.

Phosphoric acid is a very acid or sour substance, and, like chlorine, is extremely irritating to the respiratory passages. It is very readily absorbed by water, and this union is attended with so much heat as to produce a hissing sound.

This compound may be exhibited by burning a piece of phosphorus under a bell glass, when the acid will fill the glass, and descend as a fine light substance, resembling snow.

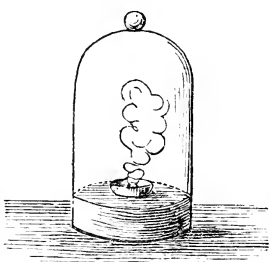

Fig. 2.

SULPHURIC ACID,

Or Oil of Vitriol, is an acid liquid of great specific gravity.

It appears like an oil when poured from a vessel, and this, together with its intense acid properties, gives it this name.

When pure, it rapidly destroys animal and vegetable substances, and chars wood when in contact with it.

Describe Phosphoric acid. How is it formed? Where does it naturally exist? What are its properties? How may its formation be exhibited?

What is sulphuric acid? What is its appearance? What its effect on organic matter?

Although naturally transparent, it is rarely seen in this condition, as the least contact with an organic substance changes it to a dark color.

It forms, when combined with various alkaline substances, a class of compounds, which are called SULPHATES. The principal of these are SULPHATE OF SODA, (Glauber Salts,) SULPHATE OF MAGNESIA, (Epsom Salts,) SULPHATE OF ALUMINA and POTASSA, (Alum,) and SULPHATE OF LIME, (Gypsum.) These compounds are called salts.

Although sulphuric acid is itself a very acrid substance, most of those salts which it contributes to form possess no such properties.

Sulphuric acid is prepared by subjecting to a high temperature those substances with which it is found naturally combined, when it distills over as an oily liquid.

The principal source of its preparation by this process is the sulphate of iron, commonly known as green vitriol.

OXIDE OF IRON

Is commonly known as iron rust. It is constantly forming by the union of oxygen of the atmosphere with iron, which may be exposed to it in moist situations.

The surface of smooth or polished iron will thus become rusted, and that rust is an oxide of this metal.

When a thin strip of iron is ignited, and then plunged into a jar which contains oxygen gas, the metal burns,

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Why is it usually of a dark color? What does it form by union with an alkali? What are the principal of these compounds?

As a class, what are these compounds called? Do these salts possess any of the original properties of the acid?

How is sulphuric acid prepared? What is its principal source? How is oxide of iron constantly forming? How is it quickly formed?

and in this process throws off many sparks, which are found to be an oxide of iron. This does not differ from that which is formed by the slow process of rusting.

The union of any metal with oxygen produces a substance which is called an oxide, and the process by which the change is effected is called oxidation.

OXIDE OF MANGANESE

Is a black mineral, and when finely pulverized, is not readily distinguished, as commonly observed, from graphite.

It exists in considerable quantities in but few localities, but is found in smaller quantities widely distributed.

It is found in considerable quantities in Bennington and Pittsford, Vermont; and in Kent, Connecticut.

It forms a small part of the ash of some plants, and is extensively distributed, but in very small quantities, in soil.

ALUMINUM and FLUORINE should be described in connection with this group, although they are not known to constitute any portion of organic substances.

ALUMINUM,

When united with oxygen, produces ALUMINA. It is nearly pure in the gems called RUBY and SAPPHIRE.

In more impure conditions, or when combined with silica, it yields the common clays.

Does oxide of iron prepared by burning iron in oxygen, differ from that formed by rusting in the atmosphere?

What is the union of any metal with oxygen called? What is the process called? What is oxide of manganese? Where found?

Are aluminum and fluorine known to form any portion of organic substances?

What does aluminum form with oxygen? What gems does it form? What does it form with silica?

The presence of ALUMINA imparts to clays those properties which fit them for the purposes of the potter, the brickmaker, the manufacturer of PORCELAIN, and of the various kinds of EARTHENWARE.

FLUORINE

Is found in combination with lime, as the FLUORIDE OF CALCIUM, or FLOUR SPAR.

It also occurs in the TOPAZ, and in some other minerals. It forms a small portion of the enamel of teeth, and of the hardest portion of the bones of animals.

The general properties of FLUORINE are not well understood, and it is known by its compounds only.

FLUORINE combines with HYDROGEN, forming HYDROFLUORIC ACID, and this compound is remarkable as possessing the power of corroding glass. The process of ETCHING upon glass was known, however, long before fluorine was suspected to exist.

CHAPTER V.

ORGANIC ELEMENTS.

THOSE substances or elements which enter into the formation of organic structures are few in number, but are found in a great variety of forms and proportions.

What properties does it impart to clay? In what combination is fluorine principally found? Where found in animal bodies?

Are its properties well understood? What does it form with hydrogen? For what used in the arts?

These are four, viz., CARBON, NITROGEN, OXYGEN, and HYDROGEN. The last three of these are gases, while the first always exists in a solid form.

CARBON

Is found in several forms and conditions, which are quite diverse in character and appearance. These are the DIAMOND, CHARCOAL, ANTHRACITE, and BITUMINOUS COAL, GRAPHITE, COKE, and LAMP-BLACK.

The DIAMOND is the hardest known substance. It is not acted upon by acids, or worn by friction, even when in contact with the hardest substances. It is, however, more readily injured by heat than many substances which are less hard; for when heated to the temperature required for melting silver, it loses its value as a gem by becoming partially charred.

The diamond is the most costly of gems. The celebrated India diamond, the KOH-I-NOOR, now the property of the British crown, has been valued at ten millions of dollars.

CHARCOAL is produced by the imperfect burning of wood, bones, and flesh.

That the burning may be rendered imperfect the material from which it is produced must be nearly covered with earth, or some other substance, that will nearly exclude the oxygen of the atmosphere. Although it appears

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What are the organic elements? In what form do oxygen, hydrogen, and nitrogen exist? In what form carbon?

What is the hardest known substance? Is it acted upon by acids or friction? What is the effect of heat upon it?

How is charcoal produced? How is the burning rendered imperfect? What are its qualities?

soft, and may be easily broken, its fine particles are so hard as to scratch the hardest glass.

ANTHRACITE and BITUMINOUS COAL are found imbedded in the earth, where they are often interposed among rocks.

The principal difference between them consists in the absence of bitumen in the anthracite, which burns with a pure flame, but is useless in the manufacture of coal gas.

GRAPHITE, also called PLUMBAGO and BLACK-LEAD, is used in the manufacture of lead-pencils, and to prevent the effects of friction in machinery. As it resists a high degree of heat, it is employed in the manufacture of crucibles.

COKE is produced by subjecting bituminous coal to a high temperature, so as to expel its bitumen, as in the manufacture of coal gas.

LAMP-BLACK is produced by the imperfect burning of bituminous substances, as the oil of pine and resin, on which it rises in the form of a dense black smoke, and is deposited in chambers prepared for its reception.

NITROGEN

Is a gas which exists in the atmosphere, and in combination with many substances which are used as food.

The other element of the atmosphere, which is oxygen, may be separated from it by placing a piece of phosphorus in a tube with a bulb, or a bolt-head, over water. A por-

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Where are anthracite and bituminous coal found? How do they differ?

What is graphite? What are its uses? What is coke? How is lamp-black produced?

Where does nitrogen exist? What other element in the atmosphere? How are these elements separated?

tion of the phosphorus will be slowly consumed, for it unites with the oxygen of the contained air.

Fig. 3.

Both the phosphorus and oxygen are engaged in the process of slow combustion, and the water will rise and fill about one-fifth of the tube.

That portion of the atmosphere which remains in the tube will prove to be nitrogen gas. This experiment proves that four-fifths of the atmosphere is nitrogen, and the remaining fifth oxygen.

If it is desired to test the gas which remains in the tube, or bell-glass, it is necessary to place the bolt-head and the vessel which contains the water (see Fig. 3) in a water trough, in order to transfer the gas to another vessel, which must be at least one-fifth smaller in order to contain nothing but the nitrogen.

NITROGEN may also be produced by burning phosphorus under a bell-glass, over water or mercury; when the oxygen of the contained atmosphere will be burned out, or unite with the phosphorus, by which process phosphoric acid is formed.

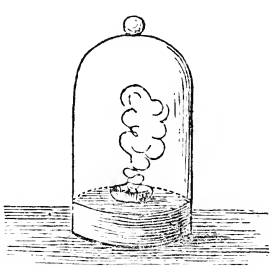

Fig. 4.

After the fumes have been absorbed, if over water, or have fallen down in white flakes upon the fluid metal, if over mercury, the contents of the bell-glass will be found to be nitrogen gas.

What change in the oxygen and phosphorus by this process? What effect on the water in the tube?

What gas remains in the tube? How else may nitrogen be produced?

Fig. 5.

When free from oxygen this gas will not sustain the life of animals, or support the flame of a candle.

To prove that it will not support flame, a lighted candle, or taper, may be lowered into a jar filled with the gas, which has been prepared by either process, when it will be extinguished.

OXYGEN.

The importance of OXYGEN will be inferred, when we learn that it forms one-fifth of the atmosphere, one-ninth of water, and not less than one-third of the whole mass of the crust of the earth.

OXYGEN, being the most extensively diffused element in nature, is found in combination with all the elements, except fluorine.

It is that portion of the atmosphere which is the chief agent in supporting animal life, and in the various processes of combustion.

Its specific gravity is greater than that of the atmosphere, the weight of which is intermediate between this substance and nitrogen. The particles of oxygen and nitrogen which compose the atmosphere are not chemically combined so as to produce a third substance, as is

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What are the properties of nitrogen? How prove that it will not support flame?

How much each of atmosphere, water, and the earth, does oxygen form?

With what elements does it combine? With which does it not combine?

What is its principal use in the atmosphere? Is it chemically combined with nitrogen?

true in the union of hydrogen and oxygen to form water, but float in relation with each other, neither of them losing their individual character.

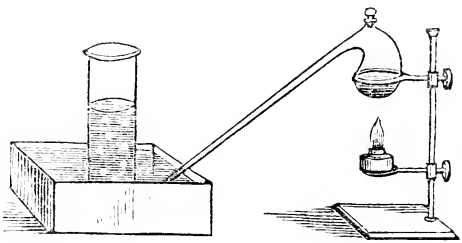

Fig. 6.

This element may be produced from several substances with which it has combined, and formed a solid. The separation of oxygen may be effected by the application of heat, varying in intensity according to the substance employed. The most convenient method for its preparation is by mixing chlorate of potash with a small quantity of the oxide of manganese in a retort, and applying heat with a spirit-lamp.

The gas may be collected in a bell-glass over a pneumatic trough. The lamp should be slowly removed from the retort, in order to secure it against breaking.

OXYGEN may also be produced in the same manner from the PEROXIDE OF MERCURY, (Red Precipitate,) but more heat is required than when chlorate of potash and manganese, or chlorate of potash alone is used.

By what means is oxygen prepared? What are the most convenient substances used in its production?

How is this gas collected? What other convenient method for its production?

This is one of the most interesting experiments which can be introduced, for both elements of which the substance used is composed, may be collected and weighed; and the fact is thus demonstrated, that no part of the materials is lost, although their appearance and properties are entirely changed.

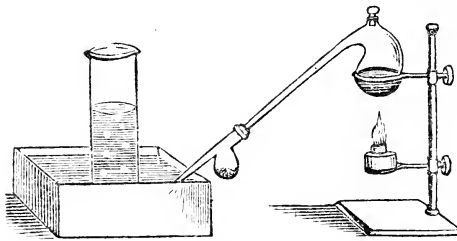

Fig. 7

By this method the mercury, (quicksilver,) which is the only metal that retains a fluid form at ordinary temperatures, may be collected in a globe, which takes the place of Wolf's bottle.

If two hundred grains of peroxide of mercury are used, one hundred and eighty-five grains of mercury will remain in the globe, and fifteen grains of oxygen will be gathered in the bell-glass over the pneumatic trough. The fifteen grains of oxygen will be found to occupy forty-four cubic inches of space.

Why is its production by the use of oxide of mercury peculiarly interesting?

If two hundred grains of oxide of mercury are used, how many grains of mercury are produced, and where found?

How many grains of oxygen? How much space will the oxygen occupy?

That oxygen, though not itself combustible, is one of the supporters of combustion, may be proved by lowering a taper, or bit of charcoal, with the smallest spark, into a jar of the gas, when it will burn with a brilliant flame, and be consumed with great rapidity; but whenever removed from the jar, the combustion ceases; but is renewed when the charcoal is returned, provided it retains the smallest ignited point. This may be rapidly repeated many times in the same jar of oxygen. (Fig. 8.)

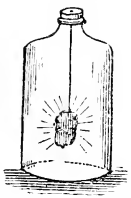

Fig. 8.

A watch-spring, or fine wire, with a glowing point, will kindle and burn very rapidly, throwing off brilliant sparks, when plunged into this gas. (Fig. 9.)

Fig. 9.

HYDROGEN.

Hydrogen forms the principal part of coal gas, which contains, also, a minute quantity of carbon, and other impurities.

Hydrogen gas is produced by pouring over some strips of zinc, or, what is better, some finely granulated zinc, or iron filings, some sulphuric acid, diluted with five parts of water.

The most convenient method for its preparation is, by the use of a common gas bottle, with a wide mouth, fitted with a cork, which is pierced by a tube, funnel-shaped at the top, and leading to the bottom of the bottle, in order

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What are the properties of oxygen? What are its relations to combustion?

What does hydrogen gas form the principal part of? How is it produced? What apparatus is used?

to facilitate the introduction of the liquid. Another tube, which must barely pierce the cork, should extend under the bell glass, over the pneumatic trough. (Fig. 10.)

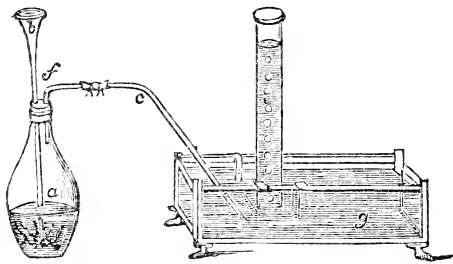

Fig. 10.

No heat is required in the preparation of this gas, but much will be evolved, if the acid is occasionally added to the mixture in the gas bottle.

Great care must be observed to avoid the mixture of atmosphere with this gas, as this combination, when inflamed, will produce a violent explosion.

When pure, hydrogen will take fire on the application of a lighted taper, and burn with a feeble flame and the most intense heat, especially when the jet is joined by one of oxygen. This union of the gases in the jet forms what is called the oxy-hydrogen blow-pipe. Hydrogen, though combustible, is not a supporter of combustion.

Any substance which is lighter than the atmosphere will rapidly escape from a vessel, unless it is inverted.

Is any heat required in its preparation? Why should we avoid a mixture of atmosphere with it when burned?

What are its properties? What effect if united with oxygen when burned?

Those substances, only, which are heavier than the atmosphere, are retained when the vessel stands upright. For this reason oxygen will remain for a short time in an upright jar, while nitrogen and hydrogen will readily escape.

Hydrogen can be tested with regard to its property of not supporting combustion, while it burns itself, only, when the mouth of the vessel is turned downward.

If a burning taper is carried upward into a bell-glass filled with hydrogen, it will be extinguished, after first setting fire to the lower surface of the gas. The gas will, however, continue to burn, until, in a few seconds, all is consumed.

Hydrogen may be prepared in a bottle with a pipe-stem or glass tube piercing the cork.

The gas will take fire by the application of flame, as it escapes from the orifice, and continue to burn with a feeble flame. This has been called the "Philosopher's lamp." The cork should not be introduced for a few moments after the mixture, in order that the air which the bottle contains may be expelled, or an explosion may take place. (Fig. 11.)

Fig. 11.

The most convenient plan for exhibiting the burning properties of this gas is by placing the materials for generating it in the bottom of a tall glass, and covering for a few moments, in order that a small quantity may accumulate.

Does hydrogen support combustion? How proved that it does not?

Describe the philosopher's lamp. What precautions are necessary in its use?

What is the most convenient plan for exhibiting the burning properties of hydrogen?

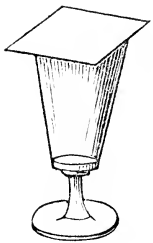

Fig. 12.

On removing the cover, and quickly applying a taper, a slight explosion will take place. (Fig. 12.)

Hydrogen gas is the lightest of all known substances, being fifteen times lighter than the atmosphere. This property renders it an appropriate material for inflating balloons.*

CHAPTER VI.

COMPOUNDS PRODUCED BY DECOMPOSITION OF ORGANIC MATTER.

THE forms which organic substances assume when decomposed, are principally three.

These forms are WATER, CARBONIC ACID, and AMMONIA; and they are compounds of the four organic elements, in various forms and proportions.

How much does 100 cubic inches of hydrogen weigh? Of nitrogen—atmosphere—oxygen—carbonic acid, and chlorine? What use does its peculiar lightness fit it for?

How many forms do organic substances assume when decomposed? Of what elements are they composed?

* NOTE.—This table indicates the comparative weight of several common substances. Fractions are omitted:

100	cubic	inches	of hydrogen	weigh	2	grains.
"	"	"	nitrogen	"	30	"
"	"	"	atmosphere	"	31	"
"	"	"	oxygen	"	34	"
"	"	"	carbonic acid	"	47	"
"	"	"	chlorine	"	76	"

WATER is composed of OXYGEN and HYDROGEN, chemically combined, in the proportion of eight parts of the former to one of the latter.

This compound is one of the sources of the elements of which it is composed, as furnished to vegetable tissues. Its principal use is a physical one, for by *its* agency, the nutritive materials appropriated by plants and animals, are conveyed through their vessels.

CARBONIC ACID is a gas, but it exists as a solid when combined with the ALKALIES and ALKALINE EARTHS. It combines with LIME, POTASH, SODA, MAGNESIA, and some other substances, and forms a class of compounds which are called CARBONATES.

Many specimens of lime rock contain in each hundred pounds, forty-four pounds of carbonic acid and fifty-six pounds of lime.

Carbonic acid gas is abundantly produced by the combustion of wood, and other substances which contain carbon.

It is also furnished to the atmosphere, in very large quantities, by the breathing of animals, by the various processes of fermentation, and by the decay of animal and vegetable matter.

Considerable quantities may also be separated from marble, chalk, and lime rock, by the application of heat, as in a lime-kiln.

Of what is water composed? What are its uses? Where does carbonic acid exist as a solid?

What class of compounds does it form with alkalies? How much carbonic acid in each 100 pounds of lime rock?

How is it abundantly produced? How is carbonic acid naturally furnished to the atmosphere? How separated from marble, chalk and lime rock?

This gas exists, free, in nature, in all well and spring water, from which it is expelled by boiling. It is so abundant in many springs as to escape in bubbles from the surface of the water, as those of Saratoga, in the State of New York, of Baden Baden and Carlsbad, in Germany, and of Pyrmont, in England.

Carbonic acid is heavier than the atmosphere in the proportion of forty-seven of the former to thirty-one of the latter, and, like chlorine, may be gathered by displacement of air from the vessel.

It sometimes accumulates in old wells, which are not used, and in deep caverns, where the air is seldom agitated, where it has long been known as CHOKE DAMP, from its fatal effects when incautiously breathed.

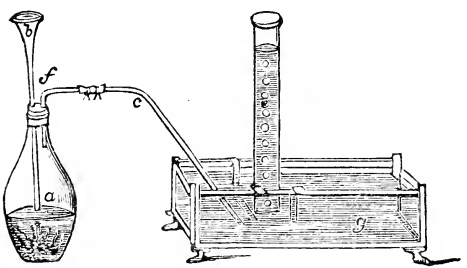

Fig. 13.

This gas may be conveniently prepared by pouring some diluted CHLOROHYDRIC ACID upon CHALK, or any of the carbonates, by which process the carbonic acid is separated.

Where does carbonic acid exist free in nature?

In what proportion is it heavier than the atmosphere? Where does it sometimes accumulate? How can it be prepared?

This gas does not support animal life or combustion. That it does not support combustion may be demonstrated by lowering a taper into a jar filled with the gas, when it will be extinguished.

Fig. 14.

That it is heavier than the atmosphere may be proved by *pouring* it from a jar, into one which has a burning taper, (figs. 14 and 15,) at the bottom, when the light is soon extinguished.

CARBONIC ACID is the principal source of food for plants, as most of the carbon which enters into their formation is derived from it.

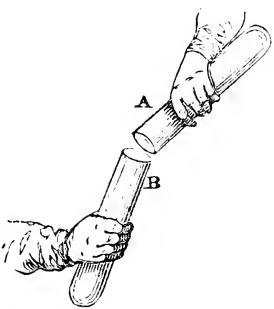

Fig. 15.

AMMONIA is a gaseous compound, and is naturally produced by the decomposition of such animal and vegetable substances as contain nitrogen. It is composed of hydrogen and nitrogen, and its composition is expressed in symbols, thus: $H_3\,N$.

It is a volatile alkali, which term distinguishes it from those which are fixed or solid.

It may be produced by heating in a flask equal quantities of slaked lime and sal ammoniac.

As it is lighter than the atmosphere, it may be col-

What are its properties? How proved that it is heavier than the atmosphere?

What does it contribute to growth of plants? What is ammonia? How naturally produced? Of what elements composed?

What kind of an alkali is it? How may it be artificially produced?

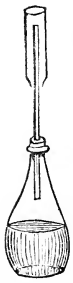

Fig. 16.

lected, by the method of displacement of air, the vessel in which it is received being inverted over the tube from which the gas escapes. (Fig. 16.)

Ammonia is remarkable for its strong affinity for water, and is consequently readily absorbed by it. This solution is called AQUA AMMONIA, and is the form in which it is most commonly sold and used.

By union with acids, like other alkalies, it forms salts, and thus loses the pungent odor peculiar to this gas.

When ammonia is combined with aromatics, it forms the smelling salts of the shops.

Ammonia is one of the most active elements of farm-yard manure; but, without great care, large quantities of this valuable fertilizer are lost from the farm-yard, and carried off in the atmosphere.

That ammonia has a strong affinity for acids may be shown by bringing a glass rod, which has been dipped in chlorohydric acid, over a vessel containing ammonia, when a dense white cloud is seen to rise, which is *chloride of ammonium*. (See Fig. 17.)

Fig. 17.

Is it heavier or lighter than the atmosphere? How proved?

For what is ammonia remarkable? In what form is it most commonly used?

Does it form salts with acids? Does it thus lose its pungent odor?

Is it an active element of manure? Why is it readily lost from manure? How proved that it has a strong affinity for acids?

CHAPTER VII.

MATERIALS OF WHICH PLANTS ARE COMPOSED.

ALL plants, among which are numbered the whole range of VEGETABLES, TREES, and GRAINS, are composed of two kinds of materials, or parts, which are distinguished by the terms ORGANIC and INORGANIC.

The ORGANIC portion is readily burned away in the fire; and this quality distinguishes it from the inorganic portion.

The INORGANIC part is not consumed by the action of fire, but remains after the organic part is burned away, and is known as their ASHES.

The organic portion of all plants is much greater than the inorganic part, but the proportion varies very greatly in the different kinds of plants, or woods. This portion varies from ninety to ninety-nine parts in a hundred, in the different grains and woods.

The elements which compose the organic part are very few in number, but they exist in a considerable variety of forms. These elements, being four in number, are CARBON, NITROGEN, or AZOTE, HYDROGEN, and OXYGEN, (See Organic Elements.)

Of what two classes of materials are plants composed? How is the organic portion separated? Which part is the greatest?

How great is the organic portion? What elements compose the organic part of plants?

CHAPTER VIII.

THE INORGANIC COMPOUNDS IN PLANTS.

THOSE inorganic substances which exist in the largest quantity in plants are as follows, and are placed in the order in which they exist in most plants in the largest proportion. They are POTASH, SODA, LIME, MAGNESIA, PHOSPHORIC ACID, SULPHURIC ACID, and SILICA. OXIDE OF IRON and OXIDE OF MANGANESE exist in plants, but in much smaller proportion.

The four first elements, or the combinations which they form, being driven off, or consumed by heat, the inorganic portion remains, but may afterward, mostly, be dissolved in water, and then gathered in troughs, while in solution.

The most common and abundant of these substances is POTASH, which is procured by the process of leaching of common wood ashes, and then evaporating the solution by boiling. Large quantities of this substance are produced in those localities which abound in forests, and sold for the purpose of manufacture into SOAP and GLASS. This article has been the source of considerable revenue from foreign countries.

SODA is much more abundant in the ashes of marine

What are the principal inorganic substances? In what condition may the inorganic substances be gathered?

Of these which is the most abundant? How is it procured? What localities produce most potash? For what purpose used in the manufactures?

plants, (kelp,) but exists, though in much smaller proportion, in the ashes of common plants and woods.

LIME forms but a small portion of the structure of plants. It constitutes a larger portion of the ashes of oats than of any other common grain. In some instances the proportion is as much as ten per cent.

MAGNESIA exists in much larger proportion in the ashes of wheat than in lime, for the proportion is nearly ten per cent. in wheat, while that of lime is less than two per cent.

PHOSPHORIC ACID is found in very large proportion in the ashes of some grains. In wheat, oats, barley, and rye, it forms between forty and fifty per cent. It exists mostly in conjunction with lime, forming the phosphate of that substance.

SULPHURIC ACID constitutes but a small proportion of the inorganic part of common plants; for it forms less than one per cent. in most of them.

SILICA, although it exists in vast quantities as a constituent of the earth, forms from less than one to more than twenty per cent. of the ashes of common grains. It is found in the largest proportion in that of barley.

OXIDE OF IRON exists in the largest proportion in oats,

In what plants is soda most abundant? In what proportion does it exist in common plants? In what plant is lime most abundant?

In what plant is magnesia most abundant? In what plants is phosphoric acid most abundant? In which does it form more than 40 per cent. of the ash?

With what is it mostly in conjunction? Does sulphuric acid constitute much of the inorganic part of plants?

What is the range of the proportion of silica in the ashes of the common grains? In the ashes of what grain is it most abundant?

in which grain it forms about five per cent. of the ashes. It forms a little more than one per cent. of the ashes of common grains.

Oxide of Manganese may be discovered in the ashes of grains, but in most of them it forms but a very small part, often much less than one per cent.

It has already been ascertained that the ashes of all plants, of whatever kind, are composed of but nine compound substances, although minute traces of a small additional number may sometimes be discovered in them, only by the most delicate tests.

These substances are destined to perform a variety of offices in the economy of common vegetables. They furnish a means of support to the stem of some, while in others they exist mostly in the fruit or berry.

CHAPTER IX.

ORGANIC COMPOUNDS IN PLANTS.

The common organic forms which exist in plants are chiefly Woody Fiber, Starch, and Gluten. Sugar, Oil, and Gum, exist as a constituent peculiar to some plants, and are much like starch in their characteristic chemical elements.

In the ashes of what grain is the oxide of iron most abundant? How much in the ashes of common grains?

Does the oxide of manganese constitute much of the ashes of common grain?

What number of compound substances in the ashes of all plants? What are the offices of these substances in plants? What are the common organic forms in plants?

WOODY FIBER is that material which forms the largest portion of all kinds of wood, of the stems of common plants, as hay, grains, and grasses, of chaff, and husks, of the shells of nuts, the fiber of cotton, flax, and hemp.

STARCH exists in great abundance in the roots of some plants. It forms nearly the entire substance of some bulbous roots, as the potato and arrow-root, and exists in large proportion in wheat and rye flour, in oat and corn-meal, and in the flour of all grains which are cultivated as food. It is also found in the stems of some plants or trees, and there is called pith.

GLUTEN exists along with starch in the flour of most kinds of grains.

It may be separated from starch in flour with which it is associated, by first wetting the flour, and making it into dough, and afterward washing with water, which should be done over a sieve or thin cloth. This will allow the starch to pass through, and the gluten will be left as a soft mass, for it is not dissolved by water.

The starch is not dissolved by this process, but its particles (granules) are so small, and so readily separated by water, as to pass through the small openings in the cloth.

Of these substances, woody fiber is most abundant in the stems of plants, while starch and gluten are mostly found in their seeds.

What is woody fiber? Where is starch found? With what is gluten associated? How may starch and gluten be separated?

How is the starch disposed of? Where is woody fiber abundant? Where is starch and gluten found?

CHAPTER X.

SUBSTANCES FORMED MOSTLY OF CARBON.

FIVE common substances which are produced by plants, consist principally of carbon. These, as before mentioned, are woody fiber, starch, gum, sugar, and oil.

The last four serve as food for men and animals, while the first is mostly useful as fuel, and as material for machinery, architecture, and the manufacture of cloth.

Carbon is the principal element in these five substances, and exists here in combination with other elements, but in quite different proportions. These other elements are oxygen and hydrogen, which are here combined in the form of water.

Every nine pounds of water are composed of eight pounds of oxygen, and one pound of hydrogen.

Every thirty-six pounds of woody fiber are composed of eighteen pounds of carbon, and eighteen pounds of water.

Every forty and a half pounds of starch or gum are composed of twenty-two and a half pounds of water, and eighteen pounds of carbon.

Eighty-five and a half pounds of loaf-sugar are com-

What five common substances consist principally of carbon? What purposes do the last four serve? What the first?

With what element is carbon here associated? In what form here do the other two elements exist?

What are the proportion of these elements in water? In thirty-six pounds of woody fiber? In forty and a half of starch or gum?

posed of forty-nine and a half pounds of water, and thirty-six pounds of carbon.

Starch, then, is composed of the same three elements which form charcoal and water. Woody fiber and gum are composed of the same elements, but in different proportions, although their appearance and uses are so unlike.

Much of the material out of which these substances are formed, is derived from the atmosphere in the form of carbonic acid, this compound being always present in the form of a gas.

CHAPTER XI.

THE ATMOSPHERE.

Atmospheric air is composed of oxygen and nitrogen gases, in the proportion of about one part of oxygen to four of nitrogen.

Although oxygen forms but one-fifth of the atmosphere, it is the active agent in the combustion of wood and coal, and in the decomposition of plants and animals.

Experiments prove that if the atmosphere was composed of pure oxygen, every organic substance would speedily be burned up, and all metals would be rapidly changed by the process of oxidation.

In eighty-five and a half of loaf-sugar? What other substances are composed of the same elements as starch?

What is the source of much of the material out of which these are built up? In what form?

Of what is the atmosphere composed? Which is the active agent in combustion and decomposition? What if the atmosphere was composed of pure oxygen?

Nitrogen seems to be supplied to the atmosphere in order to dilute its oxygen, and thus reduce the intensity of its effects.

The atmosphere contains other substances, but in small quantities. These are commonly called impurities, but they are such only with regard to animals, for they are found to promote the growth, and contribute to the health of vegetables.

Such substances, in addition to carbonic acid, are water and ammonia, (see p. 57,) and are mostly furnished to the atmosphere by the decay of vegetables and animals. However, some are furnished from other sources.

The proportion of carbonic acid in the atmosphere is about one part in twenty-five hundred, and although a large portion (at least one-half) of all vegetable substances is derived from this source, its proportion in the atmosphere is always nearly the same.

We thus learn that carbonic acid is constantly produced, and in large quantities, and is as constantly used by plants in the building up of their structure.

Carbonic acid being formed of carbon and oxygen, is composed for every twenty-two pounds of the compound, of sixteen pounds of oxygen and six pounds of carbon. Its source, in addition to the breathing of animals, and the decay of animal and vegetable substances, is by the various processes of fermentation, as of BEER, WINE, and CIDER.

What seems to be the use of nitrogen? What other substances called impurities in the atmosphere? How are these principally furnished?

What is the proportion of carbonic acid in the atmosphere? Why does the quantity not accumulate in the atmosphere? What additional sources of carbonic acid?

CHAPTER XII.

FORMS IN WHICH NUTRIMENT IS RECEIVED BY PLANTS.

THE materials out of which plants are constructed are received by them, in the form, either of liquids or gases; but every plant possesses within itself the power to change these substances, and to fit them for future use.

Plants possess the power of receiving certain inorganic materials from the earth, and so changing their properties as to fit them for contributing to the support of other plants, and of animals.

They receive carbonic acid gas from the atmosphere, through the agency of their leaves, for these are the *respiratory* organs of plants.

It has been estimated that more than a hundred and seventy thousand small openings (stomata) exist upon the surface of a leaf of some plants, while others are supplied with a much smaller number. These openings are mostly found upon the under surface of the leaf.

Leaves, then, perform important offices in the growth of plants, for they assist in the preparation of the sap, in

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In what forms are materials of which plants are constructed received by them? What an agency in the change of gases in plants?

What changes do plants themselves effect in the materials which are destined for their support?

Through what organs do they receive carbonic acid? What other office do leaves perform?

Fig. 18.

the evaporation of water, and in the separation of oxygen from the carbonic acid, which is returned again to the atmosphere. The carbon remains in order to contribute to the formation of the woody fiber, fruit, etc., and this is principally effected under the influence of light. (Fig. 18.)

CHAPTER XIII.

SOURCES OF NITROGEN.

NITROGEN is mostly furnished to plants by means of ammonia, and this element is *fixed from* ammonia by processes which to some extent correspond to the retention of carbon from carbonic acid.

AMMONIA is composed of hydrogen and nitrogen. (See p. 1.)

Seventeen pounds of ammonia are composed of three pounds of hydrogen and fourteen pounds of nitrogen, and is written in symbols thus, $N H_3$.

The muscles of animals, and that portion of plants which is called gluten, as well as vegetable albumen, consists mostly of nitrogen, but in combination with other elements.

What becomes of the carbon of the carbonic acid? What of the oxygen?

By what means are plants furnished with nitrogen? Of what is ammonia composed?

What number of atoms in each element in seventeen pounds of ammonia?

What parts of animals and plants are composed mostly of nitrogen?

When these substances are decomposed, they unite with hydrogen, and thus form ammonia, and the ammonia thus formed in turn is furnished as food for plants.

CARBONIC ACID, being largely formed by the decomposition of vegetables, AMMONIA, in like manner, is largely produced by the decomposition of animals; but a certain portion of each is formed by the decomposition of both plants and animals.

AMMONIA, like CARBONIC ACID, pervades the atmosphere, but is imbibed by plants, mostly, if not entirely, by a different set of organs. It enters into the circulation, or sap of plants, through the fine spongy extremities of their roots, (spongioles,) and consequently must first be dissolved.

WATER has the power to absorb many times its bulk of ammonia, and ammonia, in turn, has a strong tendency to approach water, and to be absorbed by it. It is by this means that *rain water*, *snow*, and *dew*, are always charged with a certain quantity of this compound, which they impart to plants, to promote their growth.

Water from wells, springs, and streams, does not contribute to the growth of plants to the same extent, unless it has previously been charged with ammonia.

When decomposed, with what does it unite? What does it thus form?

What compound is mostly formed by the decomposition of vegetables? What of the decomposition of animals?

By what organs is ammonia absorbed by plants? In what condition?

By what substance is much ammonia absorbed? What common substances contain ammonia?

Why does not well and spring water contribute as much as these to the growth of plants?

The body of an animal, by its decomposition, produces both carbonic acid and ammonia, in addition to water. Carbonic acid is furnished by the decomposition of the fatty portion, and ammonia by the muscles of animals.

A small quantity of ammonia, only, is furnished by the decomposition of vegetables, for but a limited portion of substances which contain nitrogen enter into their composition. One of these substances (carbon) is mostly received through the leaves of plants, while the other (nitrogen) is imbibed by their roots.

The substance which is derived from the atmosphere is received through the leaves of plants in the form of a gas, and the other, dissolved in water, is imbibed through their roots.

Although the atmosphere is composed of nitrogen and oxygen, (see p. 53,) we have no evidence that either of these elements furnish any material which contributes to the structure of plants.

CHAPTER XIV.

MATERIALS OF WHICH SOIL IS COMPOSED.

Soils from which plants grow, like plants themselves, are composed of organic and inorganic materials.

What substances are formed by the decomposition of animals? From what is carbonic acid furnished?

From what part is ammonia furnished? Why is so little ammonia furnished by the decomposition of vegetables?

Does nitrogen of the atmosphere furnish material for the structure of plants? Of what materials are soils composed?

This fact is proved by the same method, or that of burning.

MINERAL, or INORGANIC MATTER, is not affected by burning in such way as to diminish its weight or bulk, beyond what is lost by driving off the water which it may contain, when it escapes in the form of vapor.

If a given quantity of soil is exposed to fire, or the action of heat, a portion is consumed, or driven off, in the same manner as the organic part of wood. The ashes which remains will be the exact proportion of the inorganic part of the soil.

The organic portion of soil is derived from the roots, stems, and leaves of plants, from the excrement and remains of the various animals and insects.

The organic part of the most fertile soil composes from one-tenth to one-twentieth of its weight.

In PEATY SOILS, the organic portion is sometimes equal to three-fourths of its whole weight, but such soils are poorly adapted to the growth and support of common vegetables.

Peaty soils are unproductive, and they are so on account of their resistance to decomposition, for this is necessary in order that any soil may become food for plants.

The proportion of organic matter in soils will be diminished by the crops which are raised from them. Some

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How is this proved? How is the proportion of inorganic matter in soils determined?

From whence is the organic portion of soils derived? What is the proportion of organic material in fertile soils?

What is the proportion of organic materials in peaty soils? Are such adapted to the support of common vegetables?

Why are peaty soils unproductive? How is the organic matter in soils diminished?

materials may be removed while others remain, and this will correspond in degree, with the nature of the crops which are raised.

We learn with regard to the adaptation of a soil, for the raising of any given kind of grain, by first ascertaining what the materials are of which the grain is composed, and then the substances which exist in the soil.

A soil may be quite well adapted to the raising of one kind of grain, and at the same time poorly adapted to produce another, while the proportion of organic elements may remain about the same, but may differ in kind.

The farmer will learn with regard to the most profitable crop which he can raise from a given field by first ascertaining the particular organic materials which exist in that field.

CHAPTER XV.

SOURCES OF THE INORGANIC PORTION OF SOIL.

THE inorganic portion of soil is derived from the crumbling down of the various kinds of solid rocks.

This fact may be verified by observing the character of the earth which is found by the side of any given ledge of rocks. Such earth will be mostly composed, in its inorganic constituents, of the same materials as the rocky mass by the side of which it is found.

Does each crop remove all materials alike? May a soil be well adapted to the raising of one grain and poorly adapted to another?

How does the farmer learn to adapt his crop to a given field?

From whence is the inorganic portion of soil derived? How may this be verified?

These changes in the condition of materials of which rocks are formed, are produced by a variety of agencies. The most common, and constantly acting agency in securing such change, is the union of the original material of which the rock is formed with the oxygen of the atmosphere.

Those latitudes where the change of temperature in the different seasons is greatest, are best adapted to produce these changes, even in the most solid rocks.

The crumbling down of rocks is sometimes effected on an immense scale by the action of frost upon such masses as contain considerable water, for large fragments are often separated by the expansive force of water while freezing.

Rocks are not only broken down by these means, but smaller fragments, and particles even, are thus separated, and crumble down to fine dust. These processes furnish a soil which is composed of matter similar in its chemical constituents to the rock itself.

ROCKS WHICH FORM SOILS.

Those rocks which contribute mostly to the formation of soils are SANDSTONE, LIMESTONE, and SLATE.

SANDSTONE, which is composed mostly of silica, is of different colors, and this variation in color is principally produced by the presence of a very small quantity of some one of the different forms of iron. The largest number

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By what agencies are changes effected in the materials of which solid rocks are composed? What latitudes are best adapted to effect these changes?

How does water contribute to effect these changes? What kind of soil do these processes furnish?

What rocks contribute mostly to the formation of soils? Of what is sandstone composed? Of what colors is it found?

of sandstones are red, or white, but they are found of a great variety of hues, some of which are black, gray, and green.

LIMESTONE is found in great abundance and in many localities. The most common form is the gray lime-rock; but it is often combined with magnesia, when it takes the name of MAGNESIAN LIME-ROCK.

The next most abundant form of carbonate of lime is CHALK, which exists in large masses on the coast of England, especially along the British Channel.

MARBLE is the least abundant form of this kind of rock, but it exists in such masses, in a few localities, as to contribute to give character to soil.

Marble is found of a great variety of colors and texture, from the pure white materials used for statuary, to those which are variegated, and of various hues, some of which are used for building purposes.

SLATE or SHALE, is a source of clay soils. It is found in masses, arranged in thin layers, as those from which slates for the school-room, and slate roofing are made.

Slate is not found in as great abundance as the quantity of clay found in soils would naturally lead us to expect.

What is the most common form of limestone? What is the next most abundant form of carbonate of lime?

Does marble contribute to give character to soils? What is the source of clay soils?

In what form is slate found? Is it abundant?

CHAPTER XVI.

CLASSIFICATION OF SOIL.

SOILS are named from the amount, or proportions, of the various substances which enter into their formation.

If a soil consists principally of sand, it is called a SANDY SOIL.

If the largest portion is clay, it is called a CLAYEY SOIL.

When lime predominates, it is called a CALCAREOUS SOIL.

Those substances may exist together, but in different proportions, in the same soil, in which case it usually receives a distinct name.

A mixture of sand and clay, with a small portion of lime, is called a LOAM.

If it contain much lime, it is called a CALCAREOUS LOAM.

If it is composed of clay, with much lime, it is called a CALCAREOUS CLAY.

A certain proportion of these substances has given specific names to soils.

Pure clay, which is commonly called PIPE CLAY, is composed of about sixty parts of silica, and forty parts of

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From what are soils named? What is a sandy soil—a clay soil—a calcareous soil?

What constitutes calcareous clay? What gives specific names to soils?

What is pure clay commonly called? Of what is it composed?

alumina, with a small quantity of oxide of iron. This kind of clay contains no silicious sand which can be separated by washing with water. It forms but a small quantity of soil, and is found in comparatively few localities.

TILE CLAY forms the strongest clay soils. It consists of pure clay, mixed with from five to fifteen per cent. of silicious sand, which can be separated from it by boiling, or washing.

CLAY LOAM contains from fifteen to thirty per cent. of fine sand, which can be separated by boiling. The different parts of this soil may be very easily separated, and is consequently more easily worked. Such soil is very properly sought for in the selection of a farm.

A LOAMY SOIL contains from thirty to sixty per cent. of sand, which is retained so loosely that it can be readily separated from it by washing.

A SANDY LOAM leaves from sixty to ninety per cent. of sand.

A SANDY SOIL consists mostly of sand, and contains no more than ten per cent. of clay.

In a MARLY SOIL the proportion of lime must be more than five per cent., but less than twenty per cent.

MARLS are called SANDY, LOAMY, and CLAYEY, in accordance with the proportions they may contain of these substances, provided they be free from lime, or do not contain more than five per cent. of this material.

Does this contribute to form much soil? Of what does tile clay consist? What does clay loam contain?

Is clay loam a valuable soil? What does a loamy soil contain? A sandy loam? Sandy soil? A marly soil?

What different names are given to marly soils? What is the source of these names?

Soils are denominated CALCAREOUS when the proportion of lime exceeds twenty per cent., and thus by its quantity becomes an important constituent.

There are also CALCAREOUS CLAYS, CALCAREOUS LOAMS, and CALCAREOUS SANDS, which take their names from the proportion of clay and sand which they may contain.

VEGETABLE MOLD is sometimes a prominent characteristic of a soil.

In PEATY SOILS, its proportion may be equal to sixty and sometimes as much as seventy-five per cent.

GARDEN MOLD contains no more than five per cent. of organic matter.

CHAPTER XVII.

MANURES.

MANURES may be regarded as the food of plants, and this must be composed of the same elements as the plant itself, although they may exist in quite different forms and proportions.

The adaptation of manures to the raising of a given crop can only be learned by first acquiring a knowledge of the constituents of the crop itself.

A field, as before mentioned, may be fertile in regard to one crop, and barren in regard to another.

What soils are denominated calcareous? What gives names to calcareous clays, loams, and sands?

Does vegetable mold sometimes give character to soils? How much organic matter in garden mold?

What are manures? Of what must food of plants be composed? How do we learn to adapt manures?

The defect in a soil which renders it poorly adapted to produce a given grain, may often be readily supplied by a small expenditure of money, provided the particular defect is well understood by the farmer.

Manures, as well as the plants which they are destined to feed, are composed of both inorganic and organic materials.

The inorganic materials are mostly found in the earth from which plants grow, but whenever defective, they may be supplied by art.

Organic food for plants is furnished by the decay of other plants, which have preceded them in the same soil, or it may be furnished in the form of farm-yard manures.

FARM-YARD MANURE is usually composed of hay, straw, and excrement of animals, mixed in some instances with a small quantity of earth.

Manures are sometimes distinguished as ANIMAL, VEGETABLE, and MINERAL.

Animal and vegetable manures are used by plants only when they are decomposed into the form of carbonic acid gas, when it escapes into the atmosphere, from which it is imbibed mostly through the agency of the leaves of the plant; or, when those parts which are composed of nitrogen are decomposed into ammonia, and afterward dissolved

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How to supply defects? Of what are manures, as well as plants, composed? Is inorganic food often needed to be supplied by art?

How is their organic food furnished? Of what is farm-yard manure mostly composed?

By what names are manures distinguished? How are animal and vegetable manures changed before being used by plants?

What does their decomposition produce? By what organs is their carbonic acid taken up? By what their ammonia?

in water, in which it is mostly absorbed through their roots.

Vegetable manures are furnished by such plants, as, by their decomposition, may furnish appropriate food for a succeeding plant, which may grow from the same soil. When plants decay in the soil from which they grow, during their period of decomposition, they contribute to form vegetable mold, or mold.

To this class of manures belong HAY, STRAW, WEEDS, POTATO-TOPS, GRASS, BUCKWHEAT, RYE, and CLOVER.

GREEN GRASS and CLOVER are sometimes plowed in while growing vigorously. By this means the whole crop is added to the soil as manure, but the value of such plan will depend upon the depth at which they are buried, and the kind of soil in which they are placed.

In Great Britain, where artificial manures are most needed, the quantity of potato-tops, as manures, is much increased by breaking off the blossoms.

Having learned the constituents of plants, and of the various soils from which they grow, we may be supposed in a measure prepared to decide correctly with regard to the supply of such defects in soils as render them unequal to supply that which is demanded for the perfect growth of a given crop.

These defects in soils are accurately learned, only by the use of those tests, which chemistry teaches us to apply, except so far as one may be furnished with evi-

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How are vegetable manures furnished? During the period of decomposition of vegetable substances in soils, what do they produce?

What belong to this class? How is green grass and clover sometimes treated? How is the value of potato-tops increased?

dence by observing the character of the vegetable and animal matter which is allowed to decay in it.

Flesh of animals, by its decomposition, produces ammonia, and this substance serves to furnish materials for the formation of the nitrogenous portion of plants.

The fat of animals and the largest portion of vegetables, by their decomposition, produce carbonic acid. This contributes to build up those portions composed of carbon, whether it be for the woody fiber of the stem, or the starch, which is the principal material found in the various grains of pith, or in the roots, or gum, which is dissolved in the sap, and sometimes exudes from the bark, or cuticle; or sugar, which is also dissolved in the sap of many trees, or plants, from which it is procured by the process of evaporation by boiling; or oil, which is abundant in the seeds, and fruit, of a large number of common trees and vegetables.

The decomposition of any one of those substances which are built up of carbon, which has been derived from carbonic acid, inasmuch as they furnish this material, constitute the proper food for plants when thus disposed of.

When a soil, then, is defective in carbon, or nitrogen food, the proper remedy will be readily understood.

The refuse portions of almost any animal, or vegetable, may be employed as manure, but if we are not careful to

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How learn to supply defects of soils? What does the flesh of animals by its decomposition produce? What does this furnish to plants?

What does the fat of animals and the largest portion of vegetables furnish? What does this contribute to build up? What else used as manure?

ascertain the chemical properties of such substances, as well as of the plant we propose to raise, injury, instead of benefit, is done to the crop.

DEAD FISH, which have been cast upon the shore of seas, or lakes and rivers, are sometimes used with profit in enriching soils. These can not be used with advantage, without first being mixed with earth, or marl, so as to form a COMPOST, and this should be turned over several times before it is prepared for use as a fertilizer.

Nitrogen, or ammonia, must be furnished to most plants in order to their perfect growth, but quite different proportions are demanded by different plants.

This element is most commonly furnished by the liquid portion of farm-yard manure, and by the decay of animal substances.

It is of little consequence from whence these substances are derived, provided they are not furnished in such concentrated form as to injure the plant by their caustic properties.

When farm-yard manure, and the other common sources of these substances, do not furnish the necessary supply of nitrogen food, recourse may be had to guano.

GUANO, a bird manure, is imported from islands near the coast of Peru. Birds which frequent these islands subsist almost entirely upon fish. Their excrement is

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What care must be observed when dead fish are used? Do all plants require like proportions of ammonia?

What is its most common source? In what condition is it used by plants?

What precaution in its use? What can we have recourse to when common sources fail?

What is guano? On what do birds subsist, which produce guano?

dropped in a climate where rain is almost unknown, and where the atmosphere is so dry that but little loss of its soluble portions is sustained. This valuable fertilizer is brought from these islands by whole shiploads.

After being applied to land, if exposed to much rain, or even a moist atmosphere, much of the ammonia which it contains is lost by evaporation, unless care is taken to retain it in the soil.

This is best accomplished by plowing it in to considerable depth, when but small quantities will be brought into relation with the plant, or the atmosphere during the first season, otherwise the crop may be injured by its strength, or the caustic properties of its ammonia.

GUANO has become widely known, and much used as a manure on account of the fertility which it has been found to impart to such soils as had been regarded as worn out, and rejected as unfit for cultivation.

The fact should not be lost sight of, however, that POULTRY DUNG, STABLE MANURE, and NIGHT-SOIL, may mostly be used for the same purpose, and that the one adds to the wealth of the farmer by its importation, while the other adds to the wealth of the country as well as of the farmer, by saving the amount paid to the country where it is naturally produced.

NIGHT-SOIL is among the most valuable of manures, provided the methods for its preparation, and use are well understood by the farmer. Night-soil has long been used

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Why naturally preserved? What precautions when applied to land? What does it impart to soils?

What are home substitutes for guano? Why should these be sought in preference to guano?

by the Chinese as a fertilizer, and this may account for the large population which is sustained in that country.

When properly used, it has been found to increase the crop upon a given field, at least three-fold. If a field had produced but eight bushels of grain, the yield would at once be increased to twenty-four bushels.

In addition to this increase of the produce of a district, by proper care of night-soil, the health of its inhabitants may be promoted by this disposition of it.

If such substances are allowed to decompose and escape into the atmosphere, a noxious gas is furnished, which is injurious to the health of the inhabitants of the neighborhood.

The same means that are available for retaining such exhalations, are also effectual for preserving them, and storing them up, so that they may be used as manures, at such times as may be desired. This is most easily accomplished by mixing with them a small quantity of charcoal, prepared muck, or some other good absorbent.

The product of this mixture is called POUDRETTE.

In order to render this method most effectual, a small quantity of the substance used as an absorbent, must be added every few days.

When this method is practiced, no odors will be found to rise from the vault, as all gases are taken up by the absorbent, as soon as they escape.

In what country has night-soil been long used? How much does it increase the produce of a field?

What other purposes served by its retention by absorption? How is this effected?

What is the product of this mixture called? What care in using the proper absorbent? Why does this method prevent odors from vaults?

POUDRETTE, like guano, must be used only after being mixed with some absorbent, else the crop will be injured by the strength of the ammonia. The absorbent may as well be a portion of the soil in which it is to be placed.

POULTRY-HOUSE MANURE is much like guano in its properties as manure, and may be used in the same way. Its value is greatly increased by constant care, in adding an absorbent at very short intervals to the floor of the poultry-house.

Much of its value is soon lost, in a moist atmosphere, by evaporation and leaching.

HOG MANURE, on account of the rich quality of the food of swine, is of a superior quality, when properly prepared.

Its value is greatly increased by furnishing vegetable mold, muck, or charcoal, to the sty; for swine will work this over, and by mixing it thoroughly, save much labor to the farmer.

The manure of swine at slaughter-houses is peculiarly rich, as they are often fed upon blood, and other animal food, which render it very rich in nitrogen and the phosphates. Its ammonia is retained by mixture with absorbents, and this also protects the plant from injury.

SHEEP MANURE is less valuable, on account of the large proportion of nitrogen and mineral constituents which are appropriated in the formation of wool.

What care must be observed in using poudrette? What may the absorbent be?

What is poultry-house manure like? How may its value be increased? How naturally soon lost?

Why is this manure of superior quality? What is the manure of swine at slaughter-houses rich in? What of sheep manure? Why less valuable?

BONES contain gelatin, and this being a nitrogenous substance, ammonia is produced by its decomposition. (See page 45.)

They also contain lime and phosphoric acid, both of which belong to the class of inorganic manures. (Pages 25 and 29.)

In those countries where land is highly cultivated, on account of a necessity for its supporting a large population, many substances which have been unknown to us for such purposes, are used as manures. Among these are saw-dust, spent tan-bark, woolen rags; waste of woolen factories, paper mills, and binderies, hair, and soot.

CHARCOAL has been long used by farmers in place of manure, but with too little knowledge, (in some instances,) with regard to the manner in which it acts.

Charcoal is composed of nearly pure carbon, but does not contribute, like manures proper, to the growth of plants, by its own decomposition.

The value of charcoal resides in its remarkable power to absorb from the atmosphere, and to condense within its pores, those gases from the atmosphere and elsewhere, which serve as food for plants.

It has been computed that charcoal will absorb and condense ninety times its bulk of ammonia, thirty-five times its bulk of carbonic acid, but only nine times its bulk of oxygen, and seven times its bulk of nitrogen.

What do bones contain? What does gelatin by its decomposition produce? What else do they contain?

What substances used in countries where land is highly cultivated? Has charcoal been used in place of a manure?

Does charcoal itself contribute to the growth of plants? In what does its value reside?

How much ammonia will charcoal absorb? How much carbonic acid—oxygen—nitrogen?

It also absorbs from the atmosphere large quantities of watery vapor, which it retains in soils, and by this means contributes to retain a certain quantity of moisture during dry seasons.

These properties are possessed in a higher degree by those specimens which are finest, and consequently contain most pores, and in a lower degree by the more loose and spongy.

It has been estimated that a cubic inch of charcoal must have at least an absorbing surface of one hundred square feet. It is upon the interior surface of the pores that gases are condensed, and the quantity absorbed is in proportion to the extent of this surface.

The value of charcoal in preserving meats, and in restoring those which are tainted, depends upon its power to immediately remove the results of their decomposition.

Soot contains much carbon, and may be used in some instances in place of coal. It also contains some sulphur, and this serves as food for plants.

The ammonia which it contains is mostly in the form of a sulphate, which is not volatile, and consequently does not evaporate when applied as a top-dressing. The odor of its sulphur, when thus used, serves as a good protection against some kinds of insects. This is the source of its value when thrown upon young cabbage plants, and melon vines.

What else does it absorb? To what does this contribute? What specimens of charcoal are most valuable? Why?

What is the absorbing surface of a cubic inch of charcoal? On what does the value of charcoal in preserving meats depend?

What does soot contain? What may it sometimes be used in place of?

In what form is the ammonia which it contains? What purpose does the odor of sulphur serve?

CHAPTER XVIII.

INORGANIC MANURES.

THE inorganic or mineral manures exist naturally in sufficient quantity in many soils. In some, however, they are so defective as to require their artificial supply.

These manures act in a variety of ways, in addition to their use as furnishing food for the inorganic part of plants.

Some of these perform an office in changing both the organic and inorganic manures which exist in the soil, and thus fit them for absorption by the roots and leaves, in order that they may be assimilated by the plant.

Others seem only, or mostly, to change the mechanical condition of soils, and still others are useful as absorbers of carbonic acid and ammonia.

Some of the inorganic manures are furnished to the soil by the decay of organic manures, or the decay of certain trees and plants. The ashes of such substances are left after their decomposition, in the same manner as when their organic portion has been burned away in the fire.

If the crop which is grown from any given piece of land be at once returned to it as manure, such field will constantly increase in fertility.

Is inorganic food sufficient in most soils? In what ways do they act?

How are some inorganic manures furnished to soils? What if a crop be at once returned to a field?

The chief object in cultivating land, however, is not realized to the farmer by this process, for, like the miser, much is accumulated by the land, which is not made useful for any purpose whatever.

When we have learned the constituents of any plant, we are prepared to adapt it as a fertilizer in the most economical way.

Example.—The ashes of the potato contain more potash than any other inorganic substance, while the ashes of clover contain lime as a principal ingredient.

It is apparent, then, that each of the green crops, when used as manure, has a definite value with regard to the crop we propose to raise. As the ashes of wheat and rye contain a large proportion of potash and soda, and that of oats a larger proportion of lime than either of these, we are enabled to apply these substances in a way that will contribute to the production of these grains.

POTASH and SODA have been found in all clays, when they have been sought for, but their proportion is quite different in different localities.

LIME, in some of its forms, is the most constant and important of the inorganic constituents of soils. The most common form is that of a carbonate, as lime-rock, chalk, and marble. (See p. 62.)

The next form is as GYPSUM, or SULPHATE OF LIME.

Is the chief object in cultivating land realized by this process? What teaches how to adapt a fertilizer most economically? Give an example.

Has each green crop a definite value as a fertilizer? Mention the special value of some, and why. Where is potash and soda always found?

Which is the most constant and important of the inorganic constituents of soils? Which is the next most important?

QUICK-LIME, an oxide, is produced by heating either of the carbonates, by which their carbonic acid is expelled. (See p. 26.)

Lime is a principal inorganic ingredient of several grains and grasses, as oats and red-clover, while it exists in still larger proportion in lucerne.

It exists in very large proportion in the bones of animals, and in the shell, or outer covering of mollusks, as the oyster and clam, and of the crustacea, as lobsters and crabs, and mostly in the form of a phosphate and a carbonate.

There is no substance used in agriculture that serves such variety of purposes, as lime.

In addition to furnishing materials for animal and vegetable structure, it is used:

1. To hasten the decomposition of other substances in soils.

2. To remove excess of acids.

3. To cause the mineral matter in soils to crumble.

Lime being itself an alkali, which, when in excess, is injurious to soils, unites with acids, which are also injurious, and thus forms another substance which is called a SALT.

SALTS are the principal forms in which inorganic materials serve for the support of plants, either by contributing to their structure, or by changing the mechanical condition of soils.

Lime being an active decomposing agent, serves to

How is quick-lime produced? In what grains is lime most abundant?

Where in animals does lime exist? What different purposes does it serve in agriculture?

How useful in soil which contains acids? In what principal form is inorganic material used by plants?

hasten the decomposition of organic matters, and to separate them from the inorganic materials with which they are associated, when they escape in the form of gases, and are then in a condition to be absorbed by the roots and leaves of plants.

The action of lime upon organic substances secures their decomposition into the same elements as those of which they were originally constructed. The lime does not unite with animal and vegetable matter, and thus produce a third substance, as when it acts upon inorganic matter, or unites with acids.

When it acts upon the fat of animals, or upon the substances formed of carbon which exists in plants, the substance produced is *carbonic acid.*

By its action upon the flesh of animals, or any other organic substance which contains nitrogen, the product of such decomposition is *ammonia.*

When the substance subjected to its action is formed of both carbon and nitrogen, the result will be both *carbonic acid* and *ammonia*, and, at the same time, *water.*

The decomposition, then, of all organic substances, of whatever kind, will produce at least one, and, sometimes, all of these three substances, viz.: WATER, composed of *oxygen and hydrogen;* CARBONIC ACID, of *carbon and oxygen;* and AMMONIA, of *hydrogen and nitrogen.*

What is the effect of lime on organic matter? What substances does this decomposition produce?

Does lime ever unite with animal and vegetable matter? Does it unite with inorganic matter?

What is produced when it acts upon the fat of animals? What when it acts upon their flesh?

What will the decomposition of all organized substances produce?

As lime forms no part of these compounds, it is apparent that it acts only as an agent in securing these changes, and thus fitting them for the support of plants.

Such soils as contain an injurious quantity of acids, which render them fitted for the support of inferior plants only, as sorrels and other weeds which are themselves injurious to useful plants, will be rendered fertile with regard to most grains, by the addition of a small quantity of lime. Such lime must be in a form that does not already contain an acid. The form used for this purpose is quick-lime.

INORGANIC COMPOUNDS are so acted upon by lime as to crumble down into fine particles. By its union with some compounds of this class, both are rendered soluble.

By its union with Silica, it forms a silicate of lime. The silica in this instance seems to take the place of an acid.

The MECHANICAL changes which are produced in soils by the agency of lime, are also calculated to facilitate certain CHEMICAL changes, for the finer particles being thus exposed more fully to the influence of the atmosphere, will more readily undergo that chemical change which is called oxidation. It is also thus better prepared to absorb nutritive material for plants, from the atmosphere.

The addition of a small quantity of lime to a compact

What the use of lime, then, when thus used? What its use in improving lands which contain acids?

What must such lime not contain? What form should be used? What is the action of lime on inorganic compounds?

What substance is thus rendered soluble? What does silica seem to take the place of? What purposes do the mechanical changes which it effects, serve?

What is its effect upon compact clay?

clay, or aluminous soil, will render it loose, and thus fitted for easy cultivation.

The quantity of lime which is proper to use, should be carefully regarded in each particular case.

A proper quantity will greatly facilitate the decomposition of organic substances, while a larger quantity may produce too rapid decomposition of the same substances, and thus induce a useless waste of the best materials for the support and growth of the plant.

An excess of lime will have the effect to exhaust a soil, for that which is not readily used by the plant, escapes as gas into the atmosphere, and is lost to the field which it is designed to improve.

These gases may be stored up and used at a future time, provided some absorbent is furnished, or exists naturally in the soil.

The best artificial absorbent which can readily be provided for this purpose, is charcoal.

The most common natural absorbents are clay and alumina, especially during a long dry season, during which much ammonia is stored up for future use in the pores of these substances.

Lime should be used with much care, especially when associated with animal manures, as an excess will cause a rapid and wasteful discharge of ammonia.

Care should be observed to procure lime which is

Should its quantity here be carefully regarded? Why careful about quantity when added to organic substances?

How may gases which escape be stored up? What is the best artificial absorbent?

What are the most common natural absorbents? Why should lime be used with care when it is associated with animal manures?

What care is necessary in selecting lime?

free from impurities, the most common of which is magnesia.

The best lime for enriching soils is produced by the burning of shells, for such is free from the noxious agencies which are elsewhere found.

SULPHATE OF LIME, or GYPSUM, is also called *Plaster of Paris*, because it exists in abundance in the rocks which underlie the city of Paris.

Gypsum is made to serve two important purposes as a fertilizer, for the sulphur which it contains, supplies that element to plants.

Unlike the oxide, or quick-lime, it acts as an absorbent of ammonia.

This quality indicates the utility of sprinkling it about stables, privies, and poultry-houses, where it absorbs noxious gases, and by this means renders such places more healthful, and better fitted for the abode of animals.

When gypsum is used to excess, it promotes the growth of sorrel; for the land is rendered sour, by the separation of lime for the use of the plant, while the acid is left free in the soil. This condition is readily corrected by the addition of quick-lime.

CHLORIDE OF LIME may be easily produced by the mixture of lime and salt, or by slacking quick-lime by the use of sea-water.

It may be used to absorb ammonia and other gases, and,

What is the most common impurity? From what is the best lime produced? What purposes does gypsum serve? How unlike quick-lime?

Why should it be sprinkled about stables? What is its effect when used to excess? How is this condition corrected?

How is chloride of lime produced? For what purpose is it used?

like quick-lime, for the decomposition of animal and vegetable substances.

PHOSPHATE OF LIME, OR BONE EARTH, which is formed of phosphoric acid and lime, is one of the most common constituents of animal and vegetable substances.

It is called bone earth, because it is the form of lime which exists most largely as an earthy constituent in the bones of animals.

PHOSPHORIC ACID exists in large proportion in the ashes of various grains. It forms about one-half of the ashes of wheat, buckwheat, rye, corn, and oats; but in slightly less proportion in barley, peas, and beans. It also exists as an important substance in potatoes and turnips. About one-fourth of the ashes of milk is composed of phosphoric acid.

The various methods by which phosphoric acid is removed from soils, and the limited number of natural methods for its return, render the study of the relations of this substance to soils and plants, as well as animals, among the most important in agriculture.

Every bushel of wheat removed from a farm, takes away a little more than half a pound of phosphoric acid; or each hundred bushels of wheat removes nearly sixty pounds of this acid.

It has been estimated that each cow which feeds in a pasture during a whole summer, will remove not less than

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Of what is phosphate of lime formed? Where abundant in animals? Where does it exist in grains?

In what grain does it form much of the ashes? In what others is it an important substance?

What is its proportion in the ashes of milk? Why should the relations of phosphoric acid be carefully studied?

How much does every bushel of wheat remove? How much

fifty pounds of bone earth. As one thousand pounds is thus removed by each twenty cows, it becomes apparent that the exhaustion of pasture lands is very rapid, so that in a few years a fertile pasture may be reduced to a barren waste, and this may be true, while it contains all the other materials which are demanded in order to constitute a fertile field.

It has also been estimated that the removal of bone earth from the farms of some of the older states, has caused more emigration than all other causes combined; and this, when a limited knowledge of the constituents of soils, and of the methods for ascertaining and remedying defects, would have rendered the restoration of such fields both certain and economical.

The principal source from which phosphoric acid may be furnished to exhausted fields, is by the use of bones of animals, for these contain a large proportion of phosphate of lime.

Bones seem to be the receptacles in which large quantities of phosphoric acid are stored up, from whence it may be used by plants at such times as it may be required.

Bones, when dried, consist of about two parts of inorganic material, most of which is phosphate of lime, and one part of organic matter.

The organic portion is mostly composed of gelatin, a

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does each cow remove? Each twenty cows? What is the effect of this removal on fields? What is the source of most emigration?

How could this have been remedied? How may phosphoric acid be returned to exhausted fields?

Where is phosphoric acid stored up in animals? What do dried bones consist of? What is the organic portion mostly composed of?

compound which consists principally of nitrogen, and which, by its decomposition, like other compounds which contain nitrogen, produces ammonia.

Bones are sometimes crushed in mills, and then separated into heaps, and such heaps are composed of fragments of similar size. These are distinguished by dealers as inch, and half-inch bones, and bone-dust.

Specimens of crushed bones are selected as fertilizers, in accordance with the rapidity of the action which is desired. Bone dust will act the most rapidly, but its action will accordingly be soonest exhausted.

Whole bones are sometimes used for enriching soil, but this is the least desirable method, for their decomposition is too slow to produce the best results.

It has been estimated that one bushel of bones, properly prepared, will produce more results as a fertilizer in five years, than ten bushels used whole, or but slightly broken.

BONE BLACK is produced by burning bones in a retort, or in such way as to protect them from the atmosphere during the process. By this means all the organic portion, except carbon, will be expelled. The product of this process is called bone black, or ivory black, and consists of inorganic matter, and carbon of the bones.

The nitrogen having been disposed of, no ammonia can be formed by its decomposition. This is compensated for

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What does this produce by its decomposition? How are bones prepared for market? How distinguished by dealers?

What condition preferred as fertilizers? Why are not whole bones more used?

What is the comparative value of whole bones and bone dust? How is bone black produced?

By this process what is expelled? What does the product consist of?

by the carbon, which is retained in a form which renders it a good absorbent in the soil. The whole may be reduced to fine particles much more easily than before it was charred.

The decomposition of bones may be secured by composting them with ashes. The strongest unleached ashes should be used for this purpose. The bones should be placed in some water-tight vessel, in layers of a few inches in thickness, alternating with layers of ashes. These should be kept constantly wet.

If they become dry, or approach that condition, they will send off an offensive odor; and this is accompanied by loss of ammonia, and consequently loss of value.

The reduction of bones by this method will usually require a year. At the end of that time they may be easily washed away, when they will be readily appropriated by soils and plants, while the ashes will be of nearly equal value as a fertilizer.

Magnesia exists in small quantity in the ashes of vegetables; but its presence is so constant in soils as rarely to require its application to fields, to fit them for better sustaining a crop.

Wherever required, it may be applied in the form of magnesian lime, but this combination of magnesia already exists in many soils, in such proportion as to be injurious to its fertility.

How is the loss of nitrogen compensated for? In what other way may the decomposition of bones be secured? Describe the method.

What if allowed to become nearly dry? How much time will this reduction of bones require? What their condition at the end of a year?

Does magnesia exist in the ashes of vegetables? Is its artificial application often required? How is it applied when required?

Sulphuric acid is a very important constituent of some vegetables, especially of oats and the root crops.

For this reason it is sometimes defective in soils which have been long used for potatoes, and other root crops.

In such instances, the most convenient and economical method for supplying the defect, is by the use of plaster of Paris, from which the sulphuric acid is abstracted, and the lime is left free, in which condition it may serve for the mechanical reduction of soils.

It is sometimes desirable to add the sulphuric acid alone, especially when the use of lime would be injurious, but in such instances it must be largely diluted with water.

Sulphuric acid is sometimes added to compost heaps, in order to secure the change of ammonia, which is volatile, and escapes easily into a sulphate, which is not volatile, but is readily dissolved in water, and thus absorbed by plants.

Those who are employed in manufacturing fertilizers have sometimes paid five and even seven cents a pound for sulphate of ammonia, in order to add it to their products; while the farmer who is not informed with regard to the value of this compound, and the cheap and easy method of producing it, will throw away vast quantities of the riches of his soil.

Silica, or sand, nearly always exists in soils in sufficient

In what crops is sulphuric acid an important constituent? How is it most economically supplied when required?

What takes place when gypsum is used? When may it be necessary to add sulphuric acid alone?

What caution is necessary when it is used? For what purpose is sulphuric acid added to compost heaps? Describe the utility and economy of this plan.

quantity, but not in a proper condition for the support of plants. When the weakness of the straw of grains indicates a demand for silica, the rule is not to add silica to the soil, but such alkalies as, by combining with it, will produce silicates; for these are soluble, and readily taken up by the roots of plants.

Sand is also useful as a mechanical manure, for when mixed with stiff clay, it loosens such soil, and renders it better fitted for cultivation.

CHLORINE is a necessary constituent of plants, and when not present in soils in sufficient quantity, it may be supplied in the form of CHLORIDE OF SODIUM, (common salt,) or CHLORIDE OF LIME.

Chlorine is naturally supplied in abundance to such plants as grow near the sea-shore.

OXIDE OF IRON is one of the most commonly present substances in soils, and is seldom, if ever, required as a manure.

There are two common oxides of iron—the protoxide and the peroxide.

The protoxide exists most largely in common deep soils, and is always injurious to vegetation.

The peroxide is not only inoffensive, but actually necessary to a fertile soil.

The protoxide of iron may be readily changed to the

Is sand often required to be applied artificially? When straw of grain is weak, why not add silica? What is the proper course?

What is the utility of sand with stiff clay? How may chlorine be supplied to plants?

Where is it naturally supplied? Is oxide of iron common in soils? In what two forms?

Which is injurious to vegetation? Where does protoxide of iron exist?

peroxide, by turning up the soil which contains it quite often, so as to expose it freely to the oxygen of the atmosphere, from which it imbibes an additional atom of this element.

Oxide of Manganese is not recognized as an essential constituent of plants or soils, and is not commonly taken into the account in manuring land.

CHAPTER XIX.

DRAINAGE.

Drains, or under drains, serve a variety of purposes, and are constructed in different ways. They are mostly used for the purpose of removing surplus water, in order that land may be cultivated. While this is being accomplished, other purposes are very often unconsciously realized by the farmer.

A necessity for the removal of surplus water arises from a variety of sources, the principal of which are the presence of springs, or a subsoil which prevents the transmission of water, either upward or downward, with the facility demanded, in order to render the surface soil productive.

A soil composed mostly of clay may itself be sufficiently compact to demand the use of this means for the removal of water.

How may protoxide be changed to the peroxide? Is oxide of manganese an essential constituent of soils?

What purposes do drains serve? What soils require them most?

Clay is sometimes associated with small quantities of oxide of iron. Such stratum is often so compact as to prevent the transmission of water, nearly as effectually as the most solid rocks.

Great advantage may be conferred in such cases by sinking shafts, or wells, to such depth as to reach a layer of gravel, into which water may be received, and thus conveyed away, or absorbed.

Drains are commonly placed at a depth of two and a half to five feet; and the purposes they serve, at these different depths, vary mostly in their degree of action; and their depth will also suggest the distance from each other at which they should be placed, for the influence of a drain will extend in accordance with its depth.

Such drains as may be useful for a considerable number of years, may be cheaply arranged by placing stones of four to six inches in diameter, along the sides of a trench, and laying slabs, or other cheap boards over them, leaving a space between the rows of stones, through which the water can flow.

An early method of constructing drains, was by placing branches of trees in the bottom of the trench, filling it to considerable depth, and covering the earth immediately upon them. Others placed small stones in the bottom of the trench, and covered them in the same manner.

This plan served the purpose of a stratum of gravel, though in a less degree. If these had been covered with flat stones, or plank, in order to prevent the packing of earth into the interstices, their utility would have been greatly prolonged.

When are shafts or wells required? At what depth are drains commonly placed? How far apart? How may they be cheaply arranged?

A more recent method is by the use of earth baked like earthenware, which may be made of any form and diameter, and in sections of any length desired.

Drainage is mostly practiced for two purposes:

1. For the removal of surplus water from a locality, or from a soil; and,

2. For the purpose of bringing the materials of which a soil is composed into such relation with the atmosphere that *its* elements may contribute to the production of certain changes in the soil, and thus render it better fitted for the support of plants.

Those soils which demand this method for their improvement are mostly formed of clay, or contain a very large proportion of this material.

CLAY may be an essential ingredient of the surface soil, or, it may contribute to form a compact layer beneath the surface, and thus constitute a subsoil, which, from its compactness, may prevent the natural development of the plant by impeding the proper descent of their roots.

Such materials can not long remain as a hard layer, after the water which it contains has been drained off, so as to admit of the descent of the atmosphere; for this element is known to pervade, not only water in streams and lakes, whenever their surface is exposed, but also the earth to a considerable depth, when it is not saturated with water, and when not consolidated into a hard layer.

The PROTOXIDE OF IRON, which is often an ingredient of such hard stratum, is not only injurious, when in union

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What our present method for their construction? For what purposes are drains introduced?

What soils require drains?

with clay, by rendering it more compact, but is always injurious to plants in any situation.

When such mixture is brought to the surface by the use of the plow, or when exposed to the atmosphere through the agency of so far removing water from the soil as to admit the access of air, the PROTOXIDE OF IRON, which is injurious to plants, by receiving an additional atom of oxygen from the atmosphere, is converted into a PEROXIDE, which is a necessary material for their support and growth.

Chemical changes in soils which contain either protoxide of iron, or lime, are greatly retarded by the presence of surplus water. Such changes may be either *promoted*, or *retarded*, by the presence of water, and this will be in accordance with its amount, and the nature of the soil, for some soils are much more injuriously affected by drouth than others, and those lands which are most improved by frequent variation in the amount of water they contain, are those which are composed of lime, with clay, and a small quantity of iron.

Although the necessary action of oxygen upon a soil is prevented by excess of water, some moisture is absolutely demanded for this purpose.

When a soil is too dry, its materials can not be brought sufficiently under the influence of chemical agencies to admit the necessary changes, although the amount of watery vapor in the atmosphere even, is often sufficient for this purpose.

What does removal of water admit to soils? What change in iron does this secure?

What lands are most improved by frequent variation of amount of water they contain?

When a soil is too dry, the influence of what agencies are cut off?

When a soil is rendered loose, by draining away the surplus water which it contains, the atmosphere will gain access to its particles, to considerable depth, and thus become an agency in effecting certain mechanical changes in its condition.

Such mechanical changes in a soil will admit of those necessary chemical changes which are secured only through the agency of the atmosphere. This process also admits the absorption, by the soil, of carbonic acid and ammonia, which are here stored up, in order to become food for plants.

Drainage not only induces changes in the inorganic materials in soils, but promotes the decomposition of organic matter; for too much water prevents these changes, and renders this kind of food for plants quite useless, as means for promoting their growth.

Water may serve as a necessary solvent of the various materials which are naturally destined as food for plants, or it may act injuriously, by washing them away, so as to place them beyond the reach of the plant.

Drainage does not deprive a soil of the necessary amount of moisture, for it increases the facilities for its circulation, and thus renders it the bearer of those substances which are required by plants, as well as fits them for their support.

The roots of most plants extend to a considerable distance through the soil, those of some extend along near the surface, and others penetrate downward several feet, many of them not less than two or three.

A plant may grow luxuriantly through the early part

What other than chemical changes are secured by drainage? What double purpose does water serve?

Does drainage deprive a soil of necessary moisture? Why not?

of a season, and then droop, and fail to mature, and this because its roots have penetrated through a superficial soil, which has thus far furnished it with the necessary nutriment, but later in the season have penetrated to a layer of hard pan, or to some noxious ingredient, which, by its poisonous qualities has arrested its development.

This often takes place when the remedy would be easy and effectual by the introduction of proper drains, so as to admit of the necessary chemical changes.

A dry season is not without its utility, both to the soil and to the plant, for the observing farmer has long been acquainted with the fact, that a good crop is likely to succeed to a dry season.

The principal source of this utility is in the condensation of ammonia and of carbonic acid in the pores of such soils as are not already occupied by water; for although water is a good absorbent of ammonia, its office for this purpose is much better accomplished when in an attenuated condition, as in the form of vapor, or of snow-flakes.

The circulation of water through a soil is indispensable to render it available as a means of conveying nutriment to plants, and this, (like the circulation of the blood in animals,) does not so much depend upon its quantity, as upon the means which are provided for its transmission.

The genial shower is of little, or of no use, to a soil, when it is already occupied by water which it can not displace; and those valuable constituents which are brought down from the atmosphere, are thus carried away by the surface flow of water.

What may cause plants to fail to mature? What is the remedy? What are the utilities of a dry season? How may the natural benefits of a shower be prevented?

APPENDIX.

DIRECTIONS FOR USING APPARATUS.

More complete directions for the use of apparatus, than are contained in this treatise, or in most of the text-books, as well as special directions for conducting each experiment, have been deemed proper.

It is hoped that by this plan, some who may have omitted the introduction of experiments in the class-room, will no longer hesitate in the use of these invaluable aids.

Those who may introduce experiments for the first time, will seldom fail, provided they are vigilant in observing all the directions which are found, both in their proper place in the text, and in these special directions.

TRANSFERRING GASES.

Before the effort is made to transfer gases from one vessel to another, it will be well for those who are entirely unaccustomed to this manipulation, to imitate the process by the use of atmospheric air, over a water-trough.

This may be done in the following manner:

Place a glass* (inverted) on a shelf in the trough, in which the water rises a little above the shelf. This will

* Straight glasses, of uniform diameter, are introduced in this work, in place of the bell glass, (whenever admissible,) as they are more economical, less easily broken, and can be turned up without transfer of gases.

leave the glass full of air, which is there confined by the water, beneath the surface of which the edge of the glass rests.

Another glass, which has been inverted while beneath the surface of the water, is raised till its edge is near its surface. The edge of the glass filled with air is then carried under the one filled with water. The top of the one containing air is now slowly inclined to one side, when bubbles of air will rise through the water, the same as when gases are transferred.

The only object in repeating these manipulations before engaging in actual experiments, is to enable the operator to become familiar with the uses of the most simple apparatus, in order to avoid waste of gases.

DIRECTIONS FOR THE SEVERAL EXPERIMENTS.

EXPERIMENT I.

PREPARATION OF CHLORINE.

Put one part of oxide of manganese, and three to seven parts of chlorohydric acid, in a retort or flask. (See p. 28.)

That the precise quantity of acid is unimportant, may be inferred from the diversity of proportion directed by different authors.

When a gentle heat is applied, the chlorine will be seen to rise in the retort, being of a greenish yellow color. It may be gathered by displacement of dry air, and its ability to support combustion tested. Or, it may be re-

ceived into a jar of cold water, for this will absorb twice its bulk of the gas.

This is the most convenient method for testing the bleaching properties of chlorine; and this effect may be observed by placing in the solution some strips of colored cloth, for it is found to remove such colors as have been produced, either by vegetable or animal substances.

EXPERIMENT II.

PREPARATION OF PHOSPHORIC ACID.

Ignite a few grains of phosphorus, in a capsule or watch-glass floating upon water, and cover immediately with a glass. While the oxygen of the contained atmosphere is being rapidly consumed, or unites with the phosphorus, the water rises rapidly in the glass. (See p. 29.)

If prepared over water, the product, (phosphoric acid,) will be greedily absorbed, and may, like other acids, be tested by litmus.

When prepared over mercury, instead of water, the phosphoric acid will descend in flakes upon the surface of the fluid metal.

A common glass jar of the shops may as well be used, for the intense heat which attends the combustion of phosphorus, is quite likely to break the vessel used in this experiment.

EXPERIMENT III.

NITROGEN WITHOUT OPEN COMBUSTION.

A piece of phosphorus upon the end of a glass rod, may be carried up into the bulk, and the open end placed in water. (See p. 35.)

If the tube is not unnecessarily large, while the bulk is

of considerable size, so much of the oxygen of the contained air will be consumed in the time commonly occupied by a recitation, as to enable the class to observe that the water has risen in the tube, and occupied the place of the consumed oxygen. (See fig. 3.)

Several hours (at least twenty-four) will be required to complete this process. The exact quantity of phosphorus used is unimportant, as all action will cease when the oxygen is consumed.

Great care should be observed in handling phosphorus, as it takes fire by slight friction, or elevation of temperature, when exposed to the atmosphere. It should always be cut while under water, from which it should not be unnecessarily removed.

EXPERIMENT IV.

NITROGEN BY OPEN COMBUSTION.

This experiment is conducted the same as that for the preparation of phosphoric acid, and the same apparatus may be used.

The two experiments may be conducted as one, provided the teacher prefers to do so, for the only difference consists in the observation of results.

The plan for testing the gas is the same, and the results the same, when prepared by either method.

EXPERIMENT V.

TEST OF NITROGEN GAS.

The gas may be transferred to a gas bottle, (see fig. 5,) and then tested by lowering a taper into it, when it will readily be extinguished.

A small animal, as a mouse, will soon die when confined in this gas.

EXPERIMENT VI.

OXYGEN WITH CHLORATE OF POTASH AND MANGANESE.

Mix one hundred grains of chlorate of potash with thirty grains of manganese. The manganese should first be heated, in order to expel what moisture it may contain, which may be done on a strip of sheet iron, over a spirit-lamp.

A retort, or Florence flask may be employed, but the flask requires more care, as an additional tube must be used, which must be connected by a cork.

When the gas begins to come off, the heat should be maintained nearly uniform as long as the gas escapes. The lamp should be slowly removed, which, if neglected, the retort will be liable to be broken from cooling too rapidly.

The stopper should be removed, or the end of the tube raised above the water, in order to prevent its entrance into the retort, for, as it cools, a vacuum will be formed, which will be occupied by the water.

One hundred grains of chlorate of potash will produce forty grains of oxygen, which will measure one hundred and eighteen cubic inches.

EXPERIMENT VII.

OXYGEN WITH OXIDE OF MERCURY.

This experiment is conducted like the last, except that a bulb, or globe, is interposed between the retort and glass, into which the mercury is conducted, while the oxygen passes forward to the glass over the trough.

More heat is required than in the former experiment, and the retort will consequently be more likely to be broken, a result which is not uncommon in either case,

for these experiments are liable to be undertaken at the expense of a retort.

The last may sometimes be omitted, but its results should be carefully studied, as it is one of the most interesting experiments in chemistry.

EXPERIMENT VIII.

TEST OF OXYGEN.

When a straight jar is used for collecting oxygen, it may be turned up without transferring the gas.

A piece of charcoal, with an ignited point, held in a spoon or wire-forceps, may be lowered into the gas bottle, (see fig. 8,) when its combustion will become very rapid.

This may be removed from the bottle, and several times returned, in order to prove that oxygen, like hydrogen, will not remain ignited, when the burning body is removed.

EXPERIMENT IX.

OXYGEN BURNS METALS.

A watch-spring, or small wire, should perforate a cork which fits the mouth of a gas bottle; and when ignited, it should be pushed down as rapidly as it burns away.

EXPERIMENT X.

PREPARATION OF HYDROGEN.

The granulated zinc, or iron filings, are placed in the bottle; (see fig. 10;) some diluted sulphuric acid is poured on, and the gas allowed to generate for a short time, in order to expel the atmosphere from the flask, otherwise an explosion may take place.

The funnel tube should be carried down to the bottom

of the jar, or into the liquid, in order to prevent the escape of gas.

The diluted acid may be added through the funnel tube, as required, which will be indicated by the diminution of effervescence.

The decomposition of one ounce of zinc, will produce six hundred and fifteen cubic inches of hydrogen gas.

A glass filled with the gas, may be removed from the trough, with the mouth still downward, and a lighted taper carried quickly under it, when a slight explosion will be observed. The flame will pass up in the jar, and in a few seconds all the gas will be consumed.

Carry the lighted taper, quickly, above the burning surface, in order to prove that hydrogen does not support combustion; for it will be extinguished as soon as it passes above the flame, and be rekindled, as often as it is brought down to the burning surface.

A light balloon may be filled with the gas, when it will ascend to the ceiling.

EXPERIMENT XI.

PHILOSOPHICAL CANDLE.

Any common bottle may be used for this experiment. Put some zinc into the bottle, and pour on diluted sulphuric acid. The gas should be allowed to escape for a few moments before the cork is introduced, in order to avoid an explosion.

EXPERIMENT XII.

HYDROGEN BY CONVENIENT METHOD.

Put some zinc and diluted sulphuric acid (as in other experiments) in a tall glass, and cover. When it has

accumulated for a short time, on removing the cover and quickly applying a taper, a slight explosion will result.

This may be several times repeated while the gas is generating from the same material.

This experiment is one of the most convenient and simple, and the means for its introduction are nearly always at hand. It is quite sufficient to illustrate the burning properties of hydrogen.

EXPERIMENT XIII.

PREPARATION OF CARBONIC ACID.

Use the same apparatus as for generating hydrogen. (See fig. 10.)

Put some one of the carbonates (chalk is the most convenient) into the flask, and add diluted chlorohydric acid, or any of the common acids.

The gas is rapidly generated, and may be gathered in a glass over water, although a small quantity will be absorbed by the water.

Carbonic acid may also be gathered in a tall glass by displacement of air, the same as chlorine in the first experiment.

EXPERIMENT XIV.

TEST OF CARBONIC ACID.

Carbonic acid is tested in the same way as nitrogen, (see fig. 5,) and its effect upon combustion and animal life, will be found to be the same.

EXPERIMENT XV.

POURING CARBONIC ACID.

To prove that carbonic acid may be poured from one vessel to another, and that it will not support flame,

place a lighted candle in the bottom of a glass, and pour in the gas from another when the light will be extinguished.

EXPERIMENT XVI.

PREPARATION OF AMMONIA.

The muriate of ammonia and quicklime may be placed in a flask, and heat applied.

That ammonia is an alkali, may be proved by placing in the gas a litmus paper, which has been slightly reddened by an acid, when its blue color will be restored. The litmus may as well be reddened by carbonic acid gas.

EXPERIMENT XVII.

CHLORIDE OF AMMONIUM.

Pour some aqua ammonia into a wine-glass. Dip a glass rod in chlorohydric acid, and carry near the ammonia, when white fumes, (chloride of ammonium,) will be seen to form over the glass.

ANALYSIS OF MANURES AND CROPS.

A knowledge of the results of analysis of common manures and crops may be of much advantage to the practical farmer, for he will thus be enabled to see at a glance what are the constituents of the crop he may propose to raise from a given field, and thus be prepared to select such manures as contain the proper constituents.

Plants in different localities, and of different varieties, are sometimes found to contain a variable quantity of their common materials.

The first point to be ascertained in the analysis of soils, manures, or plants, is, with regard to the proportion of water, of organic and of inorganic matters which enter into their composition.

For soils, this is best accomplished by selecting a given quantity, which is neither more dry, nor more wet, than the average in the field from which it is taken. This should first be carefully weighed.

The proportion of water may be determined by the application of such grade of heat as will slowly expel its moisture, but will not char its organic ingredients.

When this is completed, the mass may be again weighed, when the difference in weight will exhibit the quantity of water it contained, and what remains will be the proportion of inorganic, and of organic matter.

The mass should now be subjected to the process of burning, but in such way that the ashes which result, may not be mixed with those produced by the fuel.

After the burning has been completed, but a small part of the original mass will be left, but what remains will be the exact proportion of inorganic matter, while the difference between the former and the present weight will indicate the proportion of organic material.

This process simply reveals the proportions of these three constituents, without indicating with regard to the chemical materials which composed them. To determine the chemical constituents of the organic, as well as of the inorganic matters, requires a separate analysis.

ANALYSIS OF WHEAT.*

The average composition of wheat, including the grain and straw is to each 1000:

	Grain.	Straw.
Organic matter	866	835
Inorganic matter	17	45
Water	117	120
	1000	1000

The proportion of bran and flour contained in wheat of different kinds varies considerably. The fine flour, which is composed of starch and gluten, with a very small quantity of vegetable albumen, will commonly constitute from 70 to 80 per cent., the middlings from 11 to 17 per cent., and the bran from 6 to 8 per cent.

Results of analysis by Vauquelin of two specimens of wheat, one grown in France, the other near Odessa:

Wheat.	French Wheat.	Odessa Wheat.
Starch	710	578
Gluten, Albumen	110	145
Sugar	47	85
Gum	33	49
Fixed Oil	—	—
Soluble Phosphates	—	—
Bran	—	23
Water	100	120
	1000	1000

The inorganic substances contained in wheat are also

* Access has been had to the works of Liebig, Solly, and Johnston, in the arrangement of these tables.

found to vary considerably in specimens from different fields, even when of the same variety. Different varieties, when grown from like fields, are also found to vary in their inorganic, as well as in their organic constituents.

Two specimens of wheat, according to an analysis by Way, gave the following results:

10,000 parts of ashes respectively were found to consist of:

	WHITE WHEAT.		HOPETON WHEAT.	
	Grain.	Straw.	Grain.	Straw.
Silica	263	7050	329	6710
Phosphoric Acid	4744	577	4444	705
Sulphuric Acid	—	331	trace	559
Lime	339	353	821	444
Magnesia	1405	329	967	327
Peroxide of Iron	67	14	8	154
Potash	2991	1276	3214	1003
Soda	187	68	214	85

It is apparent that data of this kind will indicate the quantity of each substance taken off from a field by each crop which is raised from it.

ANALYSIS OF BARLEY.

The kinds of materials of which barley is composed are about as follows:

Of the grain:

Organic matter	825
Inorganic matter	25
Water	150
	1000

The proportion of each substance, when produced with and without manure is as follows:

Barley.	No Manure.	Manure.
Starch	625	596
Gluten	29	59
Albumen	1	5
Sugar	50	44
Gum	47	44
Fixed Oil	1	4
Soluble Phosphates	1	7
Husk	136	136
Water	110	105

From two analyses of the grain by Way 10,000 parts of its inorganic portion, or ashes, consist of:

	I.	II.
Silica	3273	2360
Phosphoric Acid	3169	2601
Sulphuric Acid	79	272
Lime	148	279
Magnesia	745	867
Peroxide of Iron	51	9
Potash	2077	2743
Soda	456	5
Chloride of Sodium	—	860

ANALYSIS OF OATS.

Organic matter	872
Inorganic matter	28
Water	100
	1000

The proportion of proximate elements with and without manure are:

	No Manure.	Manure.
Starch	600	531
Gluten	19	44
Albumen	2	5
Sugar	64	50
Gum	70	57

	No Manure.	Manure.
Fixed Oil	3	4
Soluble Phosphates	1	6
Husk	120	170
Water	108	130

Composition of inorganic matter, or ashes in 10,000—two kinds used in analysis:

	I.	II.
Silica	3848	5003
Phosphoric Acid	2646	1887
Sulphuric Acid	110	10
Lime	354	131
Magnesia	733	825
Peroxide of Iron	49	27
Potash	1780	1970
Soda	384	135
Chloride of Sodium	92	7

ANALYSIS OF POTATOES.

The analysis of potatoes exhibit greater variety of proportions of starch, and of the azotized substances, than most of the materials used as foods.

The ultimate composition of dry potato is:

Carbon	440
Oxygen	447
Hydrogen	58
Nitrogen	15
Inorganic matter	40
	1000

The proportion of different compounds; two kinds being subjected to experiments, were found to be as follows:

	Red Potato.	Sweet Potato
Starch	155	151
Albumen	14	8
Gum	41	16
Starchy Fiber	40	82
Water	750	743
	1000	1000

Good potatoes are composed of 10 to 25 per cent. of starch, 3 to 8 of fiber, 2 to 4 of gum, and but 1 to 2 of azotized matter, which is albumen, and 70 to 80 of water.

The proportion of inorganic matter in 100,000 parts of dry potato tuber has been found to be as follows:

Potash	1291
Soda	748
Lime	106
Magnesia	104
Alumina	16
Oxide of Iron	9
Oxide of Manganese	trace
Silica	27
Sulphuric Acid	174
Phosphoric Acid	128
Chlorine	50

It will be observed that the proportion of potash in the ashes of the potato is quite remarkable.

ANALYSIS OF INDIAN CORN OR MAIZE.

Organic matter	857
Inorganic matter	13
Water	130
	1000

Dry maize contains:

Starch	712
Gluten, Albumen	123
Fixed Oil	90

Gum	4
Woody matter	59
Inorganic matter	12

In 100,000 parts of the grain, 1312 parts of inorganic matter have been found. In the straw the proportion was 3985. These were:

	Grain.	Straw.
Potash	200	189
Soda	250	4
Lime	35	652
Magnesia	128	236
Alumina	16	6
Oxide of Iron	trace	4
Oxide of Manganese	—	20
Silica	434	2708
Sulphuric Acid	17	106
Phosphoric Acid	224	54
Chlorine	8	6
	1312	3985

NOTE.

COMPLETE sets of apparatus, together with chemicals, required for repeating the experiments described in this work, have been arranged by the author, in order to facilitate their introduction into district schools.

The set contains a trough, retort stand, and spirit-lamp, together with more than thirty additional pieces.

The whole, including chemicals, are put up in a case, with lock and key, in order that they may be protected in the school-room. This apparatus will also be found sufficient for illustrating most of the lessons contained in the common text-books on chemistry.

The above are kept for sale by HENRY WARE, *No. 7 West Fourth street, Cincinnati.* PRICE $20.

GLOSSARY.

ACID—A compound, capable of uniting with bases, and thereby forming salts—turns litmus red.

ALKALI—A salifiable base, having the power of changing blue vegetable colors to a green.

ALKALINE EARTH—A term applied to magnesia, lime, etc., on account of their earthy character, and alkaline qualities.

AMMONIA—An alkali which is gaseous, or aeriform, in its uncombined state.

AROMATIC—Odoriferous, or fragrant.

ASSIMILATION—The process by which bodies convert other bodies into their own nature, or substance.

AZOTIZED—Nitrogenous—containing azote or nitrogen.

BASE—An alkali—a substance which, by union with an acid, forms a salt.

CARBONATE—A salt formed by the union of carbonic acid with a base.

CHLOROHYDRIC ACID—Muriatic acid.

COMBUSTION—The union of an inflammable substance with oxygen, or any supporter of combustion.

COMPOST—A mixture of various manuring substances for fertilizing land.

COMPOUND—Composed of two or more elements.

CRYSTALLINE—Consisting of crystals.

DECOMPOSITION—Separation of a compound substance into its original elements.

DEMONSTRATE—To exhibit a process—to prove to be certain.

DILUTE—To weaken—as an acid, or alcohol, by admixture of water.

DISPLACEMENT—To remove, and introduce a substitute.

ELEMENT—A body which can not be divided by chemical analysis.
EVAPORATION—The conversion of a fluid into vapor, which is specifically lighter than the atmosphere.
EVOLVE—To throw out—to emit.
EXHALE—To send forth, as fluid in the form of steam, or vapor.
FERMENTATION—A chemical change in animal and vegetable substances, accompanied by heat and effervescence.
FERTILIZER—Enricher of soil—a manure.
GRAPHITE—Carburet of iron—used for lead pencils; also called black lead and plumbago.
ILLUSTRATE—To explain—to make clear.
INORGANIC—Devoid of organs.
NITROGENOUS—Pertaining to nitrogen.
ORGANIC—Consisting of organs—incident to life.
PEROXIDE—The highest degree of oxidation of which a substance is capable of undergoing.
PHYSICAL—Action of material objects distinct from chemical.
PITH—The soft spongy substance in the center of the stems of plants and trees.
PNEUMATIC TROUGH—A water trough used in experiments with air and gases.
PORCELAIN—A fine earthenware—chinaware.
RESPIRATORY—Serving for respiration.
SALT—A body composed of an acid and a base.
SILEX—The name of an earth of which flint is composed.
SPECIFIC GRAVITY—Specific weight, as compared to air or water.
SYMBOL—An emblem—a representation of something else.
TISSUE—A web-like structure—the elementary structure of plants and animals.
VOLATILE—Easily evaporated.

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